CDM

Michigan Department of
Environmental Quality

Remediation and Redevelopment Division Final (Revised) Human Health Risk Assessment

Allied Paper, Inc./Portage Creek/ Kalamazoo River Superfund Site

April 2003

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REGULATORY AGENCY NOTICE:

The Michigan Department of Environmental Quality (MDEQ) was the lead agency for the preparation of the Human Health Risk Assessment (HHRA) for the Kalamazoo River. The United States Environmental Protection Agency (EPA) has worked jointly with MDEQ in the development of this HHRA and concurs with the results and conclusions presented herein.

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Executive Summary

This Executive Summary presents an overview of the Human Health Risk Assessment (HHRA) of the Allied Paper, Inc./Portage Creek/Kalamazoo River (API/PC/KR) Superfund Site. Risks and hazards were in this HHRA estimated for five populations: (1) sport angler — central tendency assumptions (2) sport anglers — high-end assumptions; (3) subsistence anglers; (4) residents, and (5) recreationalists. In all cases, risks and hazards were associated with exposures to polychlorinated biphenyls (PCBs) released into the Kalamazoo River system. Exposures to PCBs may result primarily from ingestion of fish or by direct contact with PCB contaminated floodplain soils, or inhalation of dust and volatile emissions from floodplain soil near three former river dams. Such exposures were assessed quantitatively. Other potential exposure, including ingestion, waterfowl, and turtles, and direct contact with contaminated surface water were found to be inadequately characterized by available data.

Regulatory Environment

This HHRA was developed separately from other regulatory decisions for protection of human health. A fish advisory is currently in place on parts of the Kalamazoo River and Portage Creek (MDCH 2000a). For the general population, on the Kalamazoo River between Morrow Pond Dam and Allegan Dam and on Portage Creek below Monarch Mill Pond, the advisory recommends no consumption of carp, catfish, suckers, smallmouth bass, and largemouth bass, and no more than one meal per week of all other species. For the general population, below Allegan Dam the advisory recommends no consumption of carp, catfish, and northern pike, no more than one meal per week of largemouth and smallmouth bass, and unlimited consumption of all other species.

For nursing mothers, pregnant women, women intending to have children, and children under 15 years of age, no consumption of any species is recommended for fish caught above Allegan Dam. For fish caught below Allegan Dam, the advisory recommends for women and children no consumption of carp, catfish, northern pike, smallmouth bass, and largemouth bass and suggests eating no more than one meal per month for all other species. Table E-1 presents the 2000 Michigan fish advisories for the API/PC/KR site. A survey of anglers on the Kalamazoo River was conducted by the Michigan Department of Community Health of the State of Michigan in 1994 (*Kalamazoo River Angler Survey and Biological Testing Study* [MDCH 2000b]). Despite existing advisories, this survey reported that anglers from Kalamazoo and Allegan Counties are eating on average two meals per month of various species including bass, catfish, panfish, bullheads, and carp taken from contaminated reaches of the river. More than 10 percent of anglers are eating more than one meal per week of these various species. This survey confirmed that the Kalamazoo River is an important recreational resource and, for certain subpopulations may serve as an important source of food.

Table E-1 Michigan Fish Advisory for PCBs, API/PC/KR Site

Water Body	Species	General Population Length (inches)									Women and Children Length (inches)								
		6-8	8-10	10-12	12-14	14-18	18-22	22-26	26-30	30+	6-8	8-10	10-12	12-14	14-18	18-22	22-26	26-30	30+
Kalamazoo River (from Battle Creek to Morrow Pond Dam)	Carp	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Kalamazoo River (from Morrow Pond Dam to Allegan Dam) and Portage Creek (below Monarch Mill Pond, Kalamazoo Co.)	Carp, Catfish, Suckers	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Largemouth and Smallmouth Bass					NC	NC	NC	NC						NC	NC	NC	NC	
	All other species	●	●	●	●	●	●	●	●	●	NC	NC	NC	NC	NC	NC	NC	NC	NC
Kalamazoo River (below Allegan Dam)	Carp, Catfish	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Largemouth and Smallmouth Bass					●	●	●	●						NC	NC	NC	NC	
	Northern Pike							NC	NC	NC							NC	NC	NC
	All other species	UC	UC	UC	UC	UC	UC	UC	UC	UC	■	■	■	■	■	■	■	■	■

NC = No Consumption
UC = Unlimited Consumption
● = One meal per week
■ = One meal per month

Risk Assessment Overview

An HHRA has five steps:

- Data Evaluation
- Toxicity Assessment
- Exposure Assessment
- Risk Characterization
- Uncertainty Analysis

In the Data Evaluation, available fish data collected in 1993 and 1997 were compiled and reviewed. Data were collected for several species from 11 Aquatic Biota Study Areas (ABSAs), including smallmouth bass, a representative sport fish, and carp, a representative bottom feeder. Data for these species from 1993 fish fillet samples were used in the HHRA.

While individual Aroclors were analyzed, the HHRA was based on total PCBs, as recommended by United States Environmental Protection Agency (EPA).

In the Toxicity Assessment, the potential health effects of PCBs are evaluated and toxicological benchmarks are identified which can be used to quantify cancer risks and noncancer hazard. The potential health effects of PCBs include cancer, reproductive effects and immunological effects (ATSDR 1996).

The Exposure Assessment involves developing scenarios whereby people come into contact with contaminated media (sediments, soils, fish). While exposure to many media are likely to be taking place at the site, fish ingestion and contact with contaminated floodplain soils were the only exposure pathways for which a quantitative assessment of risk and hazard was conducted. Data were deemed inadequate to evaluate two exposure pathways: inhalation of particulate and vapor phase contamination, and ingestion of waterfowl and turtles.

Three exposure scenarios were developed for fish ingestion (Table E-2): (1) the sport anglers scenario — central tendency assumptions; (2) the sport angler scenario — high-end assumptions; and (3) the subsistence angler scenario. The difference between the three fishing scenarios is reflected in different fish ingestion rates, exposure durations, species consumed, and fractions of the total fish ingested that were from a contaminated source.

Table E-2 Exposure Assumptions for Anglers

Assumption	Central Tendency Sport Angler	High-End Sport Angler	Subsistence Angler	Reference
Body Weight	70kg	70kg	70kg	EPA 1997
Fish Ingestion Rate	0.015 kg/day (24 meals/year)	0.078 kg/day (125 meals/year)	0.11 kg/day (179 meals/year)	West 1993
Fraction from Contaminated Source	1.0	0.5	1.0	
Exposure Frequency	365 days/year	365 days/year	365 days/year	EPA 1997
Exposure Duration Reproductive	30 years (cancer) 30 years (noncancer) 2-7 years (reproductive)	30 years (cancer) 30 years (noncancer) 2-7 years (reproductive)	30 years (cancer) 30 years (noncancer) 2-7 years (reproductive)	EPA 1994
Species	Smallmouth bass [1] (100%) & Smallmouth bass/Carp (76%) / (24%)	Smallmouth bass [1] (100%) & Smallmouth bass/Carp (76%) / (24%)	Smallmouth bass [1] (100%) & Smallmouth bass/Carp (76%) / (24%)	Site-Specific
Reduction Factor	50%	50%	50%	Zabik 1995
Absorption Efficiency	100%	100%	100%	ATSDR 1996

[1] Smallmouth bass are used in the HHRA to represent a trophic level 4 fish (predator) and carp are used to represent a trophic level 3 fish (bottom feeder).

These assumptions are based on work previously conducted by EPA Region V on Manistique Harbor, Michigan; Saginaw Bay, Michigan; and the Lower Fox River, Wisconsin Superfund sites. Fish ingestion rates for the sport angler are based on the *Great Lakes Water Quality Initiative Technical Support Document for Human Health Criteria and Values* (EPA 1995).

Two scenarios were evaluated for floodplain soil exposures, the nearby resident scenario and the recreationalist scenario. Exposure assumptions used to evaluate these scenarios are summarized below:

Table E-3 Residential Exposure Assumptions

Assumption	Resident	Reference
Soil Ingestion	114 mg-yr/kg-day (age adjusted)	MDNR 1995
Dermal Contact Rate	353 mg-yr/kr-day (age adjusted)	MDEQ 2000
Inhalation Rate	7.52 m^3-yr/kg-day (age adjusted)	MDNR 1995
Age	1-31 years	EPA 1997
Fraction from Contaminated Source	1.0	Site-Specific
Exposure Frequency	350 days/year (ingestion) 245 days/year (dermal)	MDNR 1995
Exposure Duration	30 years (cancer) 30 years (noncancer) 2 years (reproductive)	EPA 1997
Absorption Efficiency	0.14	EPA 1998

Table E-4 Recreational Exposure Assumptions

Assumption	Resident	Reference
Soil Ingestion	2.8 mg-yr/kg-day 47 mg-yr/kg-day 34 mg-yr/kg-day	MDNR 1995
Dermal Contact Rate	85 mg-yr/kg-day 61 mg-yr/kg-day	EPA 1997b
Inhalation Rate	1.37 m^3-yr/kg-day 1.9 m^3-yr/kg-day	EPA 1997b
Age	6 - 31 years	
Fraction from Contaminated Source	1.0	Site-Specific
Exposure Frequency	128 days	MDEQ 2000
Exposure Duration	2 years (reproductive) 24 years (immunological) 24 years (cancer)	EPA 1997b EPA 1997b EPA 1996
Absorption Efficiency	0.14	EPA 1998

Risk Characterization combines information from the data evaluation, toxicity assessment, and exposure assessment to develop estimates of cancer risk and noncancer hazard. Cancer risks are expressed as a probability of an individual developing cancer from site-related exposures, or in this case, from ingesting fish or being exposed to floodplain soil. Noncancer risk is expressed as a hazard index, which is a ratio of the estimated dose of PCBs received from an exposure to the RfD, which is the dose below which adverse effects are not expected. Two noncancer endpoints were evaluated — reproductive health effects and immunological health effects.

EPA has established an acceptable target range for carcinogenic risk of 1 in one million to 1 in 10,000, while for all Superfund sites, the acceptable risk level is established by the EPA Regional Administrator on a case-by-case basis. The Michigan

Department of Environmental Quality (MDEQ) considers risk below 1 in 100,000 to be acceptable. Both EPA and MDEQ consider hazard quotients/indices at or below 1 to be acceptable.

Summary of HHRA Results

Tables E-5 through E-10 summarize estimated risks and hazards for sport and subsistence anglers, residents, and recreationalists.

Risks and Hazards for Anglers

Tables E-5 and E-6 present risks and hazards for anglers based on average and maximum fish concentrations, respectively.

Using both average and maximum fish concentrations, cancer risks for subsistence anglers in all study areas were outside (greater than) the EPA target cancer risk range of 1 in 1 million to 1 in 10,000 and above the MDEQ risk threshold of 1 in 100,000. Hazard quotients for subsistence anglers in all study areas were greater than the acceptable EPA and MDEQ hazard quotient threshold of 1.

Using both average and maximum fish concentrations, cancer risks for both central tendency and high end sport anglers who consumed 100 percent smallmouth bass or 76 percent smallmouth bass and 24 percent carp were outside the EPA target cancer risk range and exceeded the MDEQ cancer threshold for all ABSAs with two exceptions. Cancer risks calculated using both average and maximum PCB concentrations for central tendency sport anglers consuming 100 percent smallmouth bass from ABSAs 6 and 11 were in excess of the MDEQ cancer threshold but below 1 in 10,000 (i.e., the upper limit of the USEPA range).

Using both average and maximum fish concentrations, hazard quotients for both central tendency and high end sport anglers who consume either 100 percent smallmouth bass or 76 percent smallmouth bass and 24 percent carp exceeded the EPA and MDEQ hazard quotient threshold of 1 for both the immunological and reproductive endpoints with one exception. The hazard quotient (0.8) using average concentrations for the central tendency sport angler who consumes 100 percent smallmouth bass from ABSA 11 does not exceed the hazard quotient threshold for the reproductive endpoint.

Risks and Hazards for Residents and Recreationalists

Tables E-7 and E-8 present risks and hazards for residents based on average and maximum concentrations, respectively. Table E-9 and E-10 present risks and hazards for recreationalists based on average and maximum concentrations, respectively.

Using average floodplain soil concentrations, cancer risks to residents in all three floodplain soil areas were within the EPA target cancer risk range of 1 in 1 million to 1 in 10,000, but above the MDEQ cancer risk threshold of 1 in 100,000. Using maximum floodplain soil concentrations, cancer risks were outside the EPA target cancer risk range and exceeded the MDEQ threshold.

Using both average and maximum floodplain soil concentrations, hazard indices based on immunological endpoints for residents in all three floodplain soil areas exceeded the EPA and MDEQ hazard index threshold of 1. Hazard indices (HIs) were calculated for residential and recreationalist receptors due to the summation of HQs for multiple exposure routes (i.e., ingestion, dermal contact, and inhalation of fugitive dust). Hazard indices for the reproductive endpoint exceeded 1 using maximum concentrations for all three areas. Hazard indices for the reproductive endpoint using average concentrations did not exceed 1.

Table E-5 Summary of Risks and Hazards for Subsistence and Sport Anglers Average Concentrations API/PC/KR Site

Source Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk from Ingestion of Fish					
				Subsistence		Sport - Central Tendency		Sport - High-End	
				100% SMB	76% SMB/ 24% Carp	100% SMB	76% SMB/ 24% Carp	100% SMB	76% SMB/ 24% Carp
Fish	Fish	ABSA 3,4,5 (Combined)	Total PCBs	7.6E-04	1.3E-03	1.0E-04	1.7E-04	2.7E-04	4.5E-04
		ABSA 6	Total PCBs	6.7E-04	1.1E-03	9.0E-05	1.4E-04	2.3E-04	3.7E-04
		ABSA 7	Total PCBs	1.0E-03	1.2E-03	1.4E-04	1.6E-04	3.5E-04	4.2E-04
		ABSA 8	Total PCBs	1.3E-03	1.8E-03	1.8E-04	2.4E-04	4.6E-04	6.1E-04
		ABSA 9	Total PCBs	2.2E-03	2.0E-03	3.0E-04	2.7E-04	7.8E-04	7.0E-04
		ABSA 10	Total PCBs	1.3E-03	2.2E-03	1.7E-04	3.0E-04	4.5E-04	7.8E-04
		ABSA 11	Total PCBs	3.7E-04	1.1E-03	4.9E-05	1.5E-04	1.3E-04	3.8E-04

Notes: Target cancer risk range: 1E-06 to 1E-04 (EPA); 1E-05 (MDEQ)

Source Medium	Exposure Medium	Exposure Point	Chemical	Noncarcinogenic Hazard Quotient from Ingestion of Fish					
				Subsistence		Sport - Central Tendency		Sport - High End	
				100% SMB	75% SMB/ 25% Carp	100% SMB	75% SMB/ 25% Carp	100% SMB	75% SMB/ 25% Carp
Fish	Fish	ABSA 3,4,5 (Combined)	Total PCBs	13 (R) 71 (I)	21 (R) 75 (I)	1.7 (R) 5.9 (I)	2.9 (R) 10 (I)	4.4 (R) 15 (I)	7.5 (R) 26 (I)
		ABSA 6	Total PCBs	11 (R) 39 (I)	18 (R) 63 (I)	1.5 (R) 5.3 (I)	2.4 (R) 8.4 (I)	3.9 (R) 14 (I)	6.2 (R) 22 (I)
		ABSA 7	Total PCBs	17 (R) 59 (I)	20 (R) 70 (I)	2.3 (R) 7.9 (I)	2.7 (R) 9.4 (I)	5.9 (R) 21 (I)	7.0 (R) 25 (I)
		ABSA 8	Total PCBs	22 (R) 77 (I)	29 (R) 100 (I)	3.0 (R) 10 (I)	3.9 (R) 14 (I)	7.7 (R) 27 (I)	10 (R) 36 (I)
		ABSA 9	Total PCBs	37 (R) 130 (I)	33 (R) 120 (I)	5.0 (R) 18 (I)	4.5 (R) 16 (I)	13 (R) 46 (I)	12 (R) 41 (I)
		ABSA 10	Total PCBs	21 (R) 75 (I)	37 (R) 130 (I)	2.9 (R) 10 (I)	5.0 (R) 17 (I)	7.5 (R) 26 (I)	13 (R) 45 (I)
		ABSA 11	Total PCBs	6.1 (R) 21 (I)	18 (R) 63 (I)	.82 (R) 2.9 (I)	2.4 (R) 8.5 (I)	2.1 (R) 7.5 (I)	6.3 (R) 22 (I)

Notes: Target hazard quotient: 1.0 (EPA and MDEQ)
(R): Reproductive endpoint
(I): Immunological endpoint

Using average floodplain soil concentrations, cancer risks to recreationalists in all three floodplain areas were within the EPA target risk range and below the MDEQ cancer risk threshold. Using maximum floodplain soil concentrations, cancer risks were within the EPA target risk range but above the MDEQ cancer risk threshold. The highest cancer risk using maximum concentrations was estimated for the Plainwell area where cancer risks were 4 in 100,000.

Table E-6 Summary of Risks and Hazards for Subsistence and Sport Anglers Maximum Concentrations API/PC/KR Site

				Carcinogenic Risk from Ingestion of Fish					
				Subsistence		Sport - Central Tendency		Sport - High End	
Source Medium	Exposure Medium	Exposure Point	Chemical	100% SMB	76% SMB/ 24% Carp	100% SMB	76% SMB/ 24% Carp	100% SMB	76% SMB/ 24% Carp
Fish	Fish	ABSA 3,4,5 (Combined)	Total PCBs	2.7E-03	4.8E-03	3.6E-04	6.5E-04	9.3E-04	1.7E-03
		ABSA 6	Total PCBs	2.5E-03	3.2E-03	3.3E-04	4.3E-04	8.7E-04	1.1E-03
		ABSA 7	Total PCBs	2.5E-03	3.0E-03	3.4E-04	4.0E-04	8.9E-04	1.0E-03
		ABSA 8	Total PCBs	2.9E-03	3.7E-03	3.8E-04	5.0E-04	1.0E-03	1.3E-03
		ABSA 9	Total PCBs	4.0E-03	4.1E-03	5.3E-04	5.5E-04	1.4E-03	1.4E-03
		ABSA 10	Total PCBs	1.6E-03	4.0E-03	2.2E-04	5.4E-04	5.8E-04	1.4E-03
		ABSA 11	Total PCBs	5.7E-04	1.9E-03	7.6E-05	2.6E-04	2.0E-04	6.7E-03

Notes: Target cancer risk range: 1E-06 to 1E-04 (EPA); 1E-05 (MDEQ)

				Noncarcinogenic Hazard Quotient from Ingestion of Fish					
				Subsistence		Sport - Central Tendency		Sport - High End	
Source Medium	Exposure Medium	Exposure Point	Chemical	100% SMB	75% SMB/ 25% Carp	100% SMB	75% SMB/ 25% Carp	100% SMB	76% SMB/ 24% Carp
Fish	Fish	ABSA 3,4,5 (Combined)	Total PCBs	44 (R) 150 (I)	80 (R) 280 (I)	5.9 (R) 21 (I)	11 (R) 38 (I)	15 (R) 54 (I)	28 (R) 98 (I)
		ABSA 6	Total PCBs	42 (R) 150 (I)	53 (R) 190 (I)	5.6 (R) 20 (I)	7.2 (R) 25 (I)	15 (R) 51 (I)	19 (R) 65 (I)
		ABSA 7	Total PCBs	42 (R) 150 (I)	50 (R) 170 (I)	5.7 (R) 20 (I)	6.7 (R) 23 (I)	15 (R) 52 (I)	17 (R) 61 (I)
		ABSA 8	Total PCBs	48 (R) 170 (I)	62 (R) 220 (I)	6.4 (R) 22 (I)	8.4 (R) 29 (I)	17 (R) 58 (I)	22 (R) 76 (I)
		ABSA 9	Total PCBs	66 (R) 230 (I)	68 (R) 240 (I)	8.8 (R) 31 (I)	9.1 (R) 32 (I)	23 (R) 81 (I)	24 (R) 83 (I)
		ABSA 10	Total PCBs	27 (R) 96 (I)	67 (R) 240 (I)	3.7 (R) 13 (I)	9.0 (R) 32 (I)	9.6 (R) 34 (I)	23 (R) 82 (I)
		ABSA 11	Total PCBs	9.4 (R) 33 (I)	32 (R) 110 (I)	1.3 (R) 4.4 (I)	4.3 (R) 15 (I)	3.3 (R) 12 (I)	11 (R) 39 (I)

Acceptable hazard quotient: 1.0 (EPA and MDEQ)
(R): Reproductive endpoint
(I): Immunological endpoint

Table E-7 Summary of Risks and Hazards for Residents Living Near Exposed Floodplain Soils Average Concentrations API/K/KR Site

Source Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk Exposure Routes Total	Chemical	Noncarcinogenic Hazard Index Exposure Routes Total
Floodplain Soils	Floodplain Soils	Trowbridge	Total PCBs	5.0E-05	Total PCBs	0.84 (R) 2.9 (I)
Floodplain Soils	Floodplain Soils	Otsego	Total PCBs	3.4E-05	Total PCBs	0.57 (R) 2.0 (I)
Floodplain Soils	Floodplain Soils	Plainwell	Total PCBs	4.4E-05	Total PCBs	0.74 (R) 2.6 (I)

Target cancer risk range: 1E-06 to 1E-04 (EPA); 1E-05 (MDEQ)
Acceptable hazard index: 1.0 (EPA and MDEQ)
(R): Reproductive endpoint
(I): Immunological endpoint

Table E-8 Summary of Risks and Hazards for Residents Living Near Exposed Floodplain Soils Maximum Concentrations API/PC/KR Site

Source Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk Exposure Routes Total	Chemical	Noncarcinogenic Hazard Index Exposure Routes Total
Floodplain Soils	Floodplain Soils	Trowbridge	Total PCBs	3.3E-04	Total PCBs	5.5 (R) 19 (I)
Floodplain Soils	Floodplain Soils	Otsego	Total PCBs	1.5E-04	Total PCBs	2.4 (R) 8.5 (I)
Floodplain Soils	Floodplain Soils	Plainwell	Total PCBs	3.5E-04	Total PCBs	5.8 (R) 20 (I)

Target cancer risk range: 1E-06 to 1E-04 (EPA); 1E-05 (MDEQ)
Acceptable hazard index: 1.0 (EPA and MDEQ)
(R): Reproductive endpoint
(I): Immunological endpoint

Table E-9 Summary of Risks and Hazards for Recreational Visitors to Exposed Floodplain Soils Average Concentrations API/K/KR Site

Source Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk Exposure Routes Total	Chemical	Noncarcinogenic Hazard Index Exposure Routes Total
Floodplain Soils	Floodplain Soils	Trowbridge	Total PCBs	5.3E-06	Total PCBs	0.008 (R) 0.39 (I)
Floodplain Soils	Floodplain Soils	Otsego	Total PCBs	3.6E-06	Total PCBs	0.006 (R) 0.26 (I)
Floodplain Soils	Floodplain Soils	Plainwell	Total PCBs	4.7E-06	Total PCBs	0.008 (R) 0.34 (I)

Target cancer risk range: 1E-06 to 1E-04 (EPA); 1E-05 (MDEQ)
Acceptable hazard index: 1.0 (EPA and MDEQ)

Table E-10 Summary of Risks and Hazards for Recreational Visitors to Exposed Floodplain Soils Maximum Concentrations API/PC/KR Site

Source Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk	Chemical	Noncarcinogenic Hazard Index
				Exposure Routes Total		Exposure Routes Total
Floodplain Soils	Floodplain Soils	Trowbridge	Total PCBs	3.5E-05	Total PCBs	0.58 (R) 2.5 (I)
Floodplain Soils	Floodplain Soils	Otsego	Total PCBs	1.5E-05	Total PCBs	0.26 (R) 1.1 (I)
Floodplain Soils	Floodplain Soils	Plainwell	Total PCBs	3.7E-05	Total PCBs	0.61 (R) 2.7 (I)

Target cancer risk range: 1E-06 to 1E-04 (EPA); 1E-05 (MDEQ)
Acceptable hazard index: 1.0 (EPA and MDEQ)

Using average floodplain soil concentrations, hazard indices based on both the immunological and reproductive endpoints were below the EPA and MDEQ threshold of 1.0. Using maximum concentrations, hazard indices based on the immunological endpoint exceeded the EPA and MDEQ threshold for the Plainwell (2.7), Otsego (1.1) and Trowbridge (2.5) areas. Using maximum concentrations, hazard indices based on the reproductive endpoint were all below the hazard index threshold.

Risk-Based Concentrations for Fish, Sediments and Floodplain Soils

Risk-based fish concentrations (RBC_{fish}) and sediment concentrations (RBC_{sed}) were developed to be protective of sport and subsistence anglers. Risk-based floodplain soil concentrations (RBC_{soil}) were developed to be protective of residents living near exposed floodplain soil. RBCs were developed for both cancer and noncancer endpoints. Risk-based concentrations were developed for PCBs using an allowable cancer risk of 1 in 100,000 and a noncancer hazard index of 1.0.

RBCs for Fish Tissue

Table E-11 presents risk-based and hazard-based fish concentrations (RBC_{fish}). For central tendency sport anglers who consume up to 24 meals per year of fish, a fish concentration of 0.109 mg/kg in fillets is protective of cancer endpoints, a concentration of 0.187 mg/kg in fillets is protective of the noncancer immunological endpoint. Since the immunological endpoint is more protective than the reproductive endpoint and is always a lesser concentration, the reproductive endpoint was not calculated. For high-end sport anglers who consume up to 125 meals/year of fish, a fish concentration of 0.042 is protective of cancer endpoints, a concentration of 0.072 is protective of the noncancer immunological endpoint. For subsistence anglers who consume up to 179 meals per year, a fish concentration of 0.015 mg/kg is protective of cancer endpoints, 0.025 mg/kg is protective of the noncancer immunological.

Table E-11 Risk-Based Fish Fillet Concentrations (RBC_{fish}) [1] API/PC/KR Site

Receptor	RBC_{fish} Protective of 1E-05 Cancer Risk for PCBs (mg/kg)	RBC_{fish} Protective of 1.0 Hazard Index for PCBs (mg/kg)
Sport Angler - Central Tendency Assumes 24 meals/year 0.015 kg/day	0.109	0.187
Sport Angler - High End Assumes 125 meals/year 0.078 kg/day	0.042	0.072
Subsistence Angler Assumes 179 meals/year 0.11 kg/day	0.015	0.025

[1] Concentrations protective of both carp and smallmouth bass (fish consumption was assumed to consist of 76% bass and 24% carp). Hazard index for immunological endpoint. Because RBC_{fish} based on immunological toxicity are lower than those based on reproductive toxicity, only RBC_{fish} for the immunological endpoint are presented.

For comparison, the MDCH considers their PCB fish advisory concentration of less than or equal to 0.05 mg/kg in fish to be protective at an ingestion rate of 225 meals per year (0.14 kg/day) for the general population for noncancer endpoints. The MDCH does not base its advisory on cancer risk, due to political and pragmatic considerations. For subsistence anglers, RBC_{fish} developed in this HHRA indicate that concentrations in the range of 0.015 (cancer) and 0.025 (noncancer) are needed to be protective of health. Differences between the derivations of the two noncancer values are listed in Table E-12.

Table E-12 Comparison of MDCH and HHRA Assumptions

	MDCH	HHRA
Meals/year	225	179
Average daily fish consumption (kg)	0.14	0.11
Reduction by cleaning/cooking (%)	50	50
Weight of subject (kg)	70	70
Target dose, HPV or RfD (µg/kg/day)	0.05	0.02
PCB level in fish (mg/kg)	0.05	0.025

Most of the difference between the two results can be attributed to the difference between the health protection value (HPV) used by the MDCH (0.05 mg/kg/day) and the EPA RfD used in the HHRA (0.02 mg/kg/day). These values were derived from the same data by different methodologies. The Great Lakes Fish Advisory Task Force used a "weight of evidence" approach to derive the HPV used by the MDCH from data on a wide range of health effect endpoints. The EPA derives RfDs from data on specific endpoints with uncertainty and modifying factors added.

The MDCH Division of Environmental Epidemiology has reviewed this document and considers it to be adequately consistent with the MDCH protocol for issuing fish consumption advisories. Although there are differences between the cleanup levels and the MDCH first Level of Concern as cited above, MDCH considers the parameters and assumptions used in the two derivations are reasonable, the resulting levels to be reasonably close, and the cleanup levels to be more protective than the MDCH Level of Concern. MDCH acknowledges the EPA and MDEQ's authority to establish the cleanup levels to be used at any site.

RBCs for In-Stream Sediments

Table E-13 presents the risk-based and hazard-based sediment concentrations (RBC_{soil}). RBC_{fish} were used to develop RBC_{sed}. RBC_{sed} represent the sediment concentrations protective of fish that are consumed at the ingestion rates specified for sport and subsistence anglers. RBC_{sed} were developed using the biota-to-sediment accumulation factor (BSAF) method presented in Region V EPA guidance (Pelka 1998). RBC_{sed} using the MDEQ cancer threshold as the target cancer risk range from 0.51 mg/kg protective of sport anglers who consume 100 percent game fish such as bass to 0.04 mg/kg protective of subsistence anglers who consume 76 percent smallmouth bass and 24 percent bottom feeding fish such as carp. RBC_{sed} using the MDEQ and USEPA noncancer hazard quotient threshold of 1.0 as the target HQ range from 0.88 mg/kg for sport anglers consuming 100 percent bass to 0.07 mg/kg for subsistence anglers assumed to consume 76 percent bass and 24 percent carp.

Table E-13 Risk-Based Sediment Concentration (RBC_{sed}) Protective of Smallmouth Bass and Carp (mg/kg sediment) API/PC/KR Site

Scenario	RBC_{sed} Protective of Fish Ingestion at 1E-05 Cancer Risk for PCBs (mg/kg)		RBC_{sed} Protective of Fish Ingestion at 1.0 Hazard Quotient for PCBs (mg/kg)	
	Bass	Bass/Carp	Bass	Bass/Carp
Sport Angler - Central Tendency	0.51	0.30	0.88	0.52
Sport Angler - High End	0.20	0.12	0.34	0.20
Subsistence Angler	0.07	0.04	0.12	0.07

RBC for Floodplain Soil

Table E-14 presents the risk-based floodplain soil concentration (RBC_{soil}) protective of residents. These RBC_{soil} would be protective of residents exposed to contaminated soil via ingestion, dermal contact, and inhalation. For the cancer endpoint the RBC_{soil} is 2.5 mg/kg. For noncancer endpoints, the RBC_{soil} is 15 mg/kg for the reproductive endpoint and 4 mg/kg for the immunological endpoint.

Table E-14 Risk-Based Floodplain Soil Concentrations (RBC_{soil}) Protective of Residents API/PC/KR Site

Receptor	RBC_{soil} Protective of 1E-05 Cancer Risk (mg/kg)	RBC_{soil} Protective of 1.0 Hazard Index (mg/kg)
Resident	2.5	15 (R) 4.0 (I)

Notes (R) = Reproductive endpoint
(I) = Immunological endpoint

Table E-15 presents the risk-based floodplain soil concentration (RBC_{soil}) protective of recreationalists. These RBC_{soil} would be protective of recreationalists exposed to contaminated soil via ingestion, dermal contact, and inhalation. For the cancer endpoint, the RBC_{soil} is 23 mg/kg. For noncancer endpoints, the RBC_{soil} is 139 mg/kg for the reproductive endpoint and 32 mg/kg for the immunological endpoint.

Table E-15 Risk-Based Floodplain Soil Concentrations (RBC_{soil}) Protective of Recreational Visitors API/PC/KR Site

Receptor	RBC_{soil} Protective of 1E-05 Cancer Risk (mg/kg)	RBC_{soil} Protective of 1.0 Hazard Index (mg/kg)
Resident	23	139 (R) 32 (I)

Notes: (R) = Reproductive endpoint
(I) = Immunological endpoint

As with any health risk assessment, exposure assumptions made introduce uncertainty into the results and conclusions. This uncertainty does not, however, preclude use of HHRA results in risk management decisions. In particular, the HHRA is believed to provide a range of risks and hazards that are conservative (i.e., likely to err on the side of protection of human health).

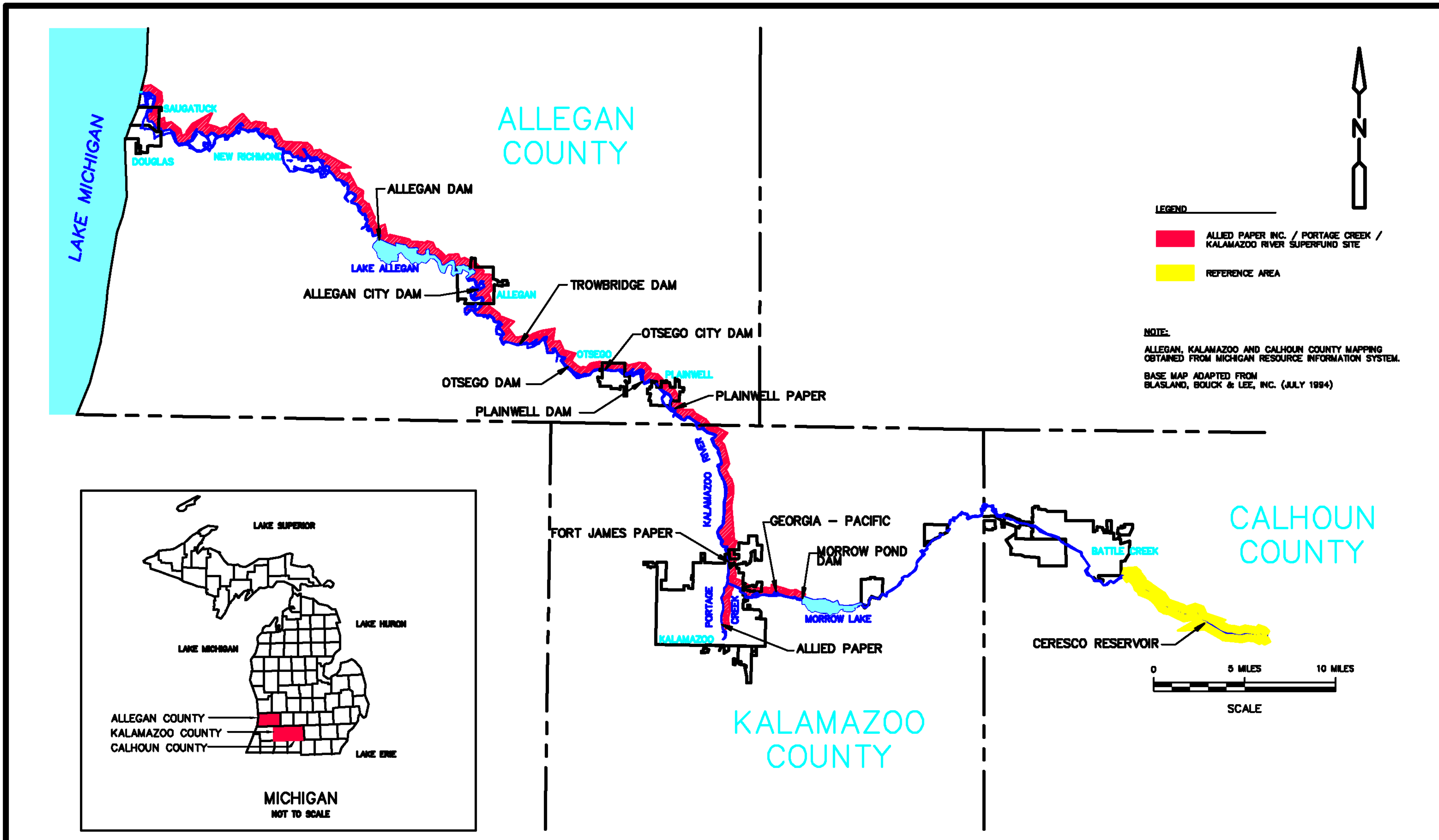
Section 1
Introduction

This document presents the human health risk assessment (HHRA) for the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site (API/PC/KR) in Southwestern Michigan. Figure 1-1 presents the extent of the site study area. This assessment is based on concentrations of polychlorinated biphenyls (PCBs) detected in media at the site, exposure assumptions for people living on and near the site, and toxicity information for PCBs, which together are used to characterize risks to human receptors. Risks are estimated based on existing (baseline) conditions, that is, in the absence of any remedial action or institutional controls. This information is intended for use by risk managers in making risk management decisions to protect human receptors.

1.1 Report Objectives

The objective of the HHRA is to assess potential current and foreseeable future risks associated with PCB exposure to people who may recreate on and near the river and along the floodplain, and who may live near the river and along the floodplain. Specifically, this HHRA:

- Defines the sources of contamination
- Identifies human receptors of concern
- Evaluates all exposure pathways and eliminate those not deemed significant
- Quantitatively evaluates significant exposure pathways
- Determines the extent and likelihood of actual or potential impacts
- Describes the uncertainty associated with the risk and hazard estimates
- Develops risk-based fish concentrations protective of human health
- Develops risk-based sediment and floodplain soil concentrations protective of human health



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KALAMAZOO RIVER HUMAN HEALTH RISK ASSESSMENT
STUDY AREA

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Figure No. 1–1

Exposures to the following media are evaluated: (1) exposed sediments/floodplain soil in former impoundment areas; (2) near and in-stream sediment; (3) surface water; (4) biota, including fish and waterfowl; and (5) air. This HHRA estimates cancer and noncancer risks for those exposure pathways considered potentially significant and for which sufficient data were available to support such calculations. In an effort to focus resources on those pathways with the greatest hazard potential, potentially significant pathways were determined by means of a comparison of API/PC/KR site data with similar data collected from the Lower Fox River and Lower Green Bay Estuary in Wisconsin. A full quantitative HHRA was conducted for these water bodies under the direction of the Wisconsin Department of Natural Resources (WDNR).

Assuming that similar exposure assumptions are appropriate for both the Michigan and Wisconsin sites, pathways found to be significant in the Lower Fox/Green Bay site were evaluated in the API/PC/KR assessment. Exceptions were made when detected concentrations were substantially lower at the API/PC/KR site.

1.2 Scope

This HHRA evaluates potential current and foreseeable future risks to people who may recreate on or live near the Kalamazoo River and its floodplain. The range of possible exposures to river water, sediment, biota, and floodplain soil were examined. For some types of exposure, a quantitative assessment of cancer risk and noncancer hazard was conducted. For other types of exposure, only a qualitative evaluation was conducted because previous investigations for a similar site found such exposures to not be associated with a significant risk, given similar or higher media concentrations.

PCB contamination is the primary focus of this HHRA and the only chemical of concern evaluated for the site. This HHRA focuses on the following two populations:

- People who may recreate on or near the Kalamazoo River and the floodplain
- People who may live near the Kalamazoo River and the floodplain

A separate HHRA has been conducted for the King Highway Landfill Operable Unit, a Georgia Pacific property along the Kalamazoo River (Blasland, Bouck & Lee [BB&L] 1996, 1997), and for the Willow Boulevard/A-Site (Camp Dresser & McKee Inc. [CDM] 2000).

1.3 Report Organization

This HHRA is being conducted under contract to the Michigan Department of Environment Quality (MDEQ) and follows guidance and directives issued by both the MDEQ and the U.S. Environmental Protection Agency (EPA).

The organization of this report follows the general format outlined in Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual (Part A). The remainder of this report is organized as follows:

- Section 2 – Data Evaluation
- Section 3 – Exposure Assessment
- Section 4 – Toxicity Assessment
- Section 5 – Risk Characterization
- Section 6 – Determination of Risk – Based Sediment and Floodplain Soil Concentrations
- Section 7 – Uncertainty Assessment
- Section 8 – References

Section 2
Data Evaluation

This HHRA evaluates potential current and foreseeable future risks to people who may recreate on or live near the Kalamazoo River and its floodplain. The range of possible exposures to river water, sediment, biota, and floodplain soil were examined. For some types of exposure, a quantitative assessment of cancer risk and noncancer hazard was conducted. For other types of exposure, only a qualitative evaluation was conducted because previous investigations for a similar site found these exposures to not be associated with a significant risk, given similar or higher media concentrations.

This section evaluates available data collected on and near the API/PC/KR site and determines whether data are adequate for conducting a quantitative or qualitative risk assessment.

2.1 Data Evaluation

Samples have been collected from fish, turtle, sediment, and surface water from the Kalamazoo River since 1971. The majority of the data used in this HHRA were collected in 1993 and 1997 and were reported in various technical memoranda prepared by BB&L, including Draft Technical Memorandum 12 – Former Impoundment Sediment and Geochronological Dating Investigation; Draft Technical Memorandum 14 (and addenda) – Biota Investigation; and Draft Technical Memorandum 5 – Willow Boulevard/A-Site Operable Unit: Results of Air Investigation.

Exposures to fish, turtle, floodplain soil, sediment, surface water, air, and waterfowl were considered in this risk assessment. Based on a review of these exposures, one of the following determinations was made for each exposure scenario/pathway under consideration:

- Quantitative evaluation of the associated exposure is needed
- Qualitative evaluation of the associated exposures is sufficient
- Additional data are needed to adequately evaluate the associated exposure

2.1.1 Fish Data

Fish data were collected in 1993 and 1997 as part of the Biota Investigation (BB&L 1994e, 1998). Several species of fish were collected including smallmouth bass, golden redhorse, carp, and spotted and white suckers. These data have been summarized and discussed in *Ecological Risk Assessment for the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site* (CDM June 1999).

Two species, smallmouth bass and carp, were selected to represent a popular targeted sport fish and a bottom feeding fish in the human health assessment. The 1993 fish tissue data included skin-off fillet data for carp and skin-on fillet data for smallmouth bass. These data were used for the risk assessment calculations. *Guidance for Assessing*

Chemical Contaminant Data for Use in Fish Advisories (EPA 1995) recommends that samples be prepared in a manner that best represents the edible portions of fish prepared and consumed by anglers. Concentrations of PCBs detected in fish fillets are presented in Table 2-1 for each of the seven areas evaluated in this risk assessment. To aid in the evaluation of aquatic habitats and chemical exposure, the API/PC/KR site was divided into 12 Aquatic Biota Study Areas (ABSAs). Nine of these ABSAs were evaluated as exposure areas in the HHRA. A list of these ABSAs is presented on Table 2-2. ABSAs 1 and 2 are located upstream of known sources associated with the API/PC/KR site and serve as reference areas for PCB contamination in fish tissues.

Table 2-1 Smallmouth Bass and Carp Data, API/PC/KR Site

	Total Aroclor			
Area/Species	**Frequency of Detection**	**Range of Detection (mg/kg)**	**Average Conc. (mg/kg)**	**Maximum Conc. (mg/kg)**
ABSA 3, 4, 5 Combined				
Small Mouth Bass	44/44	0.09 - 3.9	0.95	3.9
Carp	44/44	1.1 - 17	5.7	17
ABSA 6				
Small Mouth Bass	11/11	0.27 - 3.7	0.99	3.7
Carp	11/11	1.1 - 8.0	3.4	8.0
ABSA 7				
Small Mouth Bass	11/11	0.39 - 3.7	1.5	3.7
Carp	11/11	0.71 - 6.4	2.7	6.4
ABSA 8				
Small Mouth Bass	11/11	0.74 - 4.2	1.9	4.2
Carp	11/11	1.3 - 9.6	4.6	9.6
ABSA 9				
Small Mouth Bass	11/11	0.23 - 5.8	3.3	5.8
Carp	21/21	0.099 - 6.5	1.8	6.5
ABSA 10				
Small Mouth Bass	11/11	1.1 - 2.4	1.9	2.4
Carp	11/11	1.9 - 17	7.6	9.1
ABSA 11				
Small Mouth Bass	21/22	0.13 - 4.3	0.54	8.3
Carp	22/22	0.36 - 17	4.9	17

ABSA: Aquatic Biota Study Area. See Table 2-2 for description of ABSAs.

Table 2-2 API/PC/KR Biological Study Areas

ABSA 3	Kalamazoo River from Morrow Dam to Mosel Ave., Kalamazoo Aquatic biota were collected just downstream of Morrow Dam.
ABSA 4	Kalamazoo River at Mosel Ave. to Hwy. 131 bridge. Aquatic biota were collected from the Kalamazoo River near Mosel Avenue.
ABSA 5	Kalamazoo River near Hwy 131 bridge to Plainwell Dam. Aquatic biota were collected from the Kalamazoo River upstream of Plainwell Dam. Includes TBSAs 8, 9, and 10.
ABSA 6	Kalamazoo River from Plainwell Dam to Otsego City Dam. Aquatic biota were collected from the Kalamazoo River upstream of Otsego City Dam. Includes TBSA 10.
ABSA 7	Kalamazoo River from Otsego City Dam to Otsego Dam. Aquatic biota were collected just upstream of Otsego Dam.
ABSA 8	Kalamazoo River from Otsego Dam to Trowbridge Dam. Aquatic biota were collected upstream of Trowbridge Dam. Includes TBSA 3 and 5.
ABSA 9	Kalamazoo River from Trowbridge Dam to Lake Allegan Dam. Aquatic biota were collected from Lake Allegan.
ABSA 10	Kalamazoo River from Lake Allegan Dam to Ottawa Marsh. Aquatic biota were collected downstream of Allegan Dam. Includes TBSA 1.

Table 2-2 API/PC/KR Biological Study Areas

ABSA 11	Kalamazoo River from Ottawa Marsh to US 31. Aquatic biota were collected near Saugatuck.

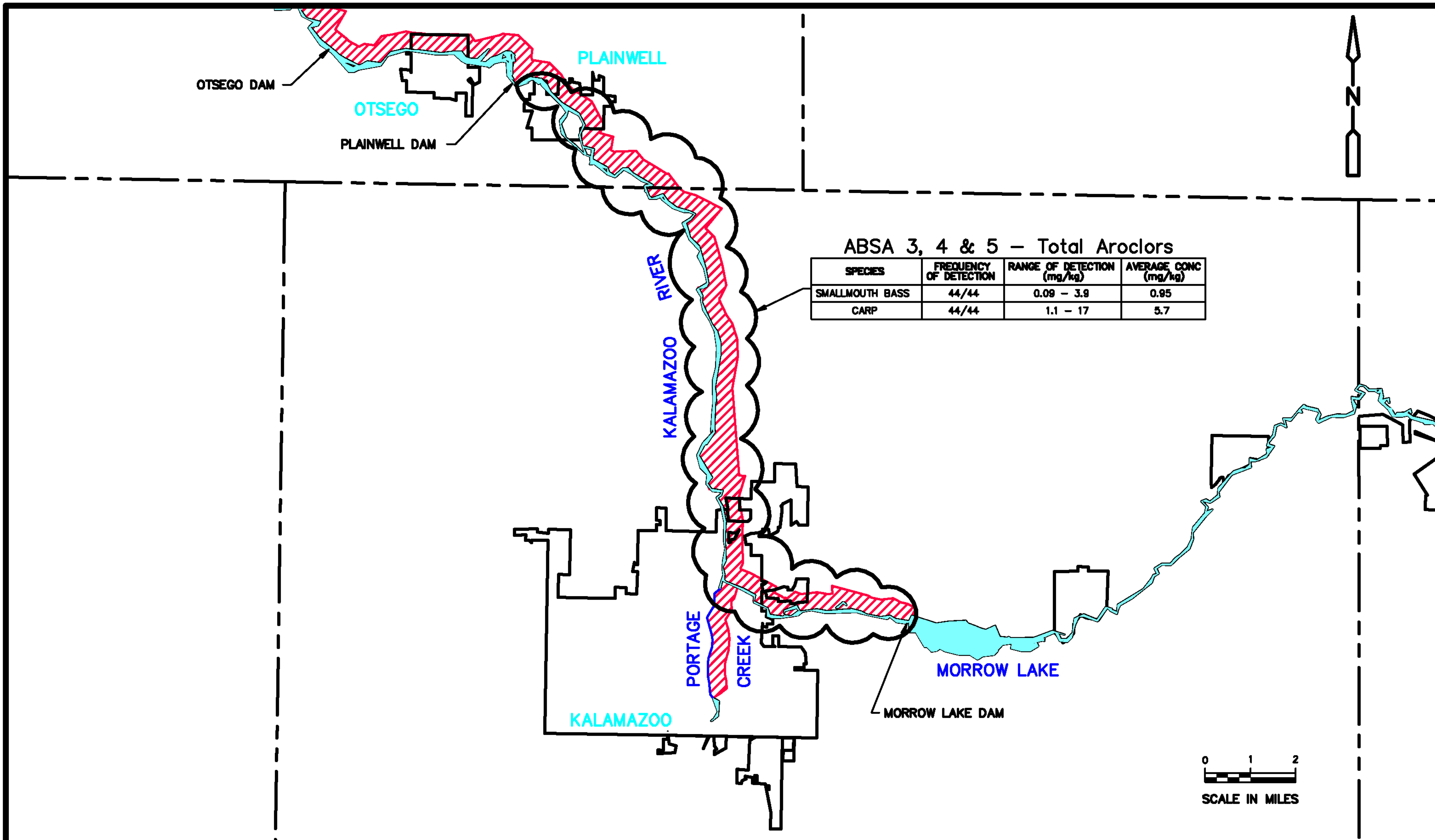
Note: ABSAs 1 and 2 are located upstream of Morrow Dam.

Three ABSAs, 3, 4, and 5, cover the area between Morrow Dam and Plainwell Dam. Data from these three ABSAs were combined for purposes of this assessment because it is assumed that fish can migrate within these areas, but due to the presence of the dams, will not migrate to adjacent ABSAs (i.e., ABSAs 2 and 6). After combining ABSAs 3, 4, and 5, all data sets represent a stretch of the river between two dams. Figures 2-1 through 2-4 illustrate fish data collected from the nine HHRA study areas.

Between 11 and 22 fish fillet samples for each species (smallmouth bass and carp) were collected for each ABSA. Quality control data is presented in Draft Technical Memorandum 14 – Biota Investigation (BB&L 1994) and generally conforms to the data quality objectives established for the site. For these reasons, fish data sets were considered adequate for risk assessment purposes. Because fish ingestion is the primary exposure pathway of concern for this site, this pathway was evaluated quantitatively. Risks and hazards were calculated using both average and maximum tissue concentrations.

2.1.2 Turtle Data

Taking of snapping turtles for consumption is known to occur in the vicinity of the site. While not well documented, the quantities of turtles ingested by individuals are believed to be less than the quantities of fish ingested. Representative data for PCB concentrations in turtle tissue are not available. Eleven turtle samples were collected from ABSAs 5 and 10. Detected concentrations of PCBs in turtles were reported in the Biota Investigation. Aroclor 1260 was detected in 11 out of 11 samples from ABSA 5, and 9 out of 11 samples from ABSA 10. Aroclor 1254 was detected one time in a sample from ABSA 10 at 0.53 mg/kg. Concentrations of Aroclor 1260 ranged from 0.021 to 0.49 mg/kg at ABSA 1 (reference area), 0.23 to 1.9 mg/kg at ABSA 5, and 0.11 to 8.1 mg/kg at ABSA 10. Turtles were collected from May 16 through May 21, 1994. Because samples were collected in the spring, lipid levels would likely be at their lowest. Similarly, concentrations of PCBs, which accumulate in fatty tissue, would also be lower at this time of year. Turtle samples collected later in the summer or fall would likely exhibit higher lipid levels and, possibly, higher PCB levels. Available data may under-represent PCB concentrations to which people ingesting turtles caught later in the summer and fall would be exposed.



ABSA 3, 4 & 5 – Total Aroclors

SPECIES	FREQUENCY OF DETECTION	RANGE OF DETECTION (mg/kg)	AVERAGE CONC (mg/kg)
SMALLMOUTH BASS	44/44	0.09 – 3.9	0.95
CARP	44/44	1.1 – 17	5.7

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KALAMAZOO RIVER HUMAN HEALTH RISK ASSESSMENT
ABSA 3, 4 & 5

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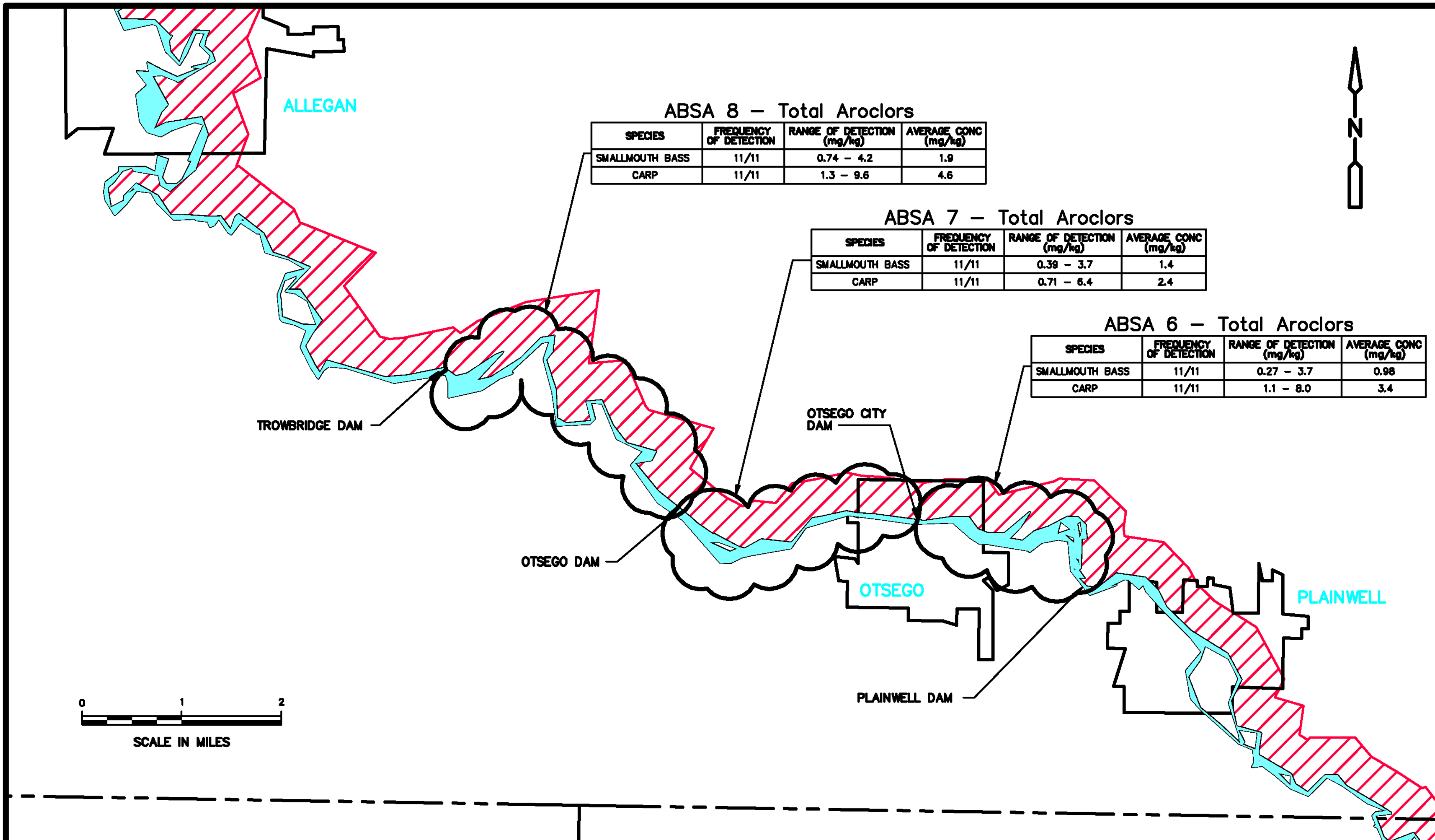
Figure No. 2-1



ABSA 8 – Total Aroclors

SPECIES	FREQUENCY OF DETECTION	RANGE OF DETECTION (mg/kg)	AVERAGE CONC (mg/kg)
SMALLMOUTH BASS	11/11	0.74 – 4.2	1.9
CARP	11/11	1.3 – 9.6	4.6

ABSA 7 – Total Aroclors

SPECIES	FREQUENCY OF DETECTION	RANGE OF DETECTION (mg/kg)	AVERAGE CONC (mg/kg)
SMALLMOUTH BASS	11/11	0.39 – 3.7	1.4
CARP	11/11	0.71 – 6.4	2.4

ABSA 6 – Total Aroclors

SPECIES	FREQUENCY OF DETECTION	RANGE OF DETECTION (mg/kg)	AVERAGE CONC (mg/kg)
SMALLMOUTH BASS	11/11	0.27 – 3.7	0.98
CARP	11/11	1.1 – 8.0	3.4

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ABSA 6, 7 & 8

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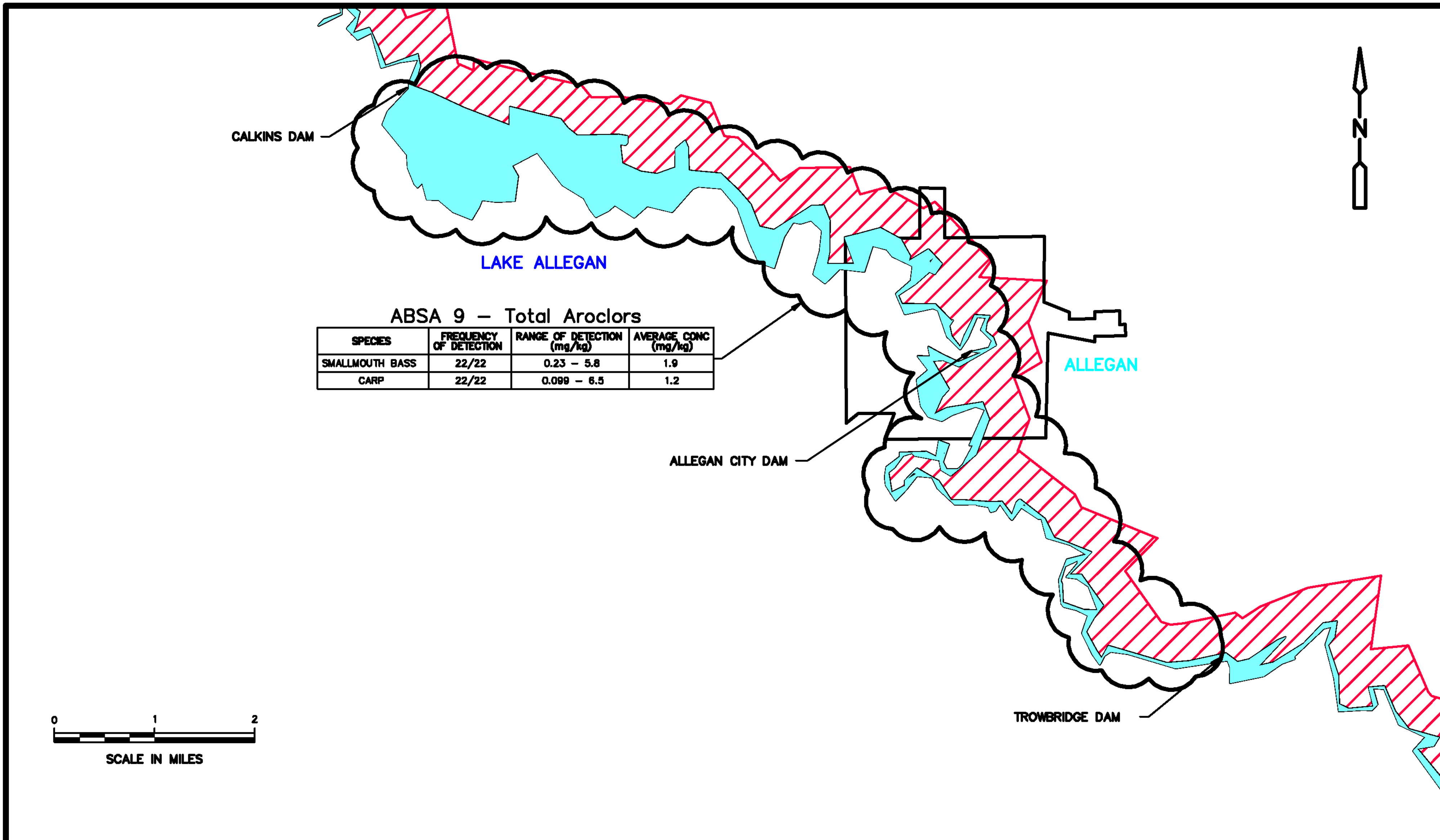
Figure No. 2-2



ABSA 9 – Total Aroclors

SPECIES	FREQUENCY OF DETECTION	RANGE OF DETECTION (mg/kg)	AVERAGE CONC (mg/kg)
SMALLMOUTH BASS	22/22	0.23 – 5.8	1.9
CARP	22/22	0.099 – 6.5	1.2

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KALAMAZOO RIVER HUMAN HEALTH RISK ASSESSMENT
ABSA 9

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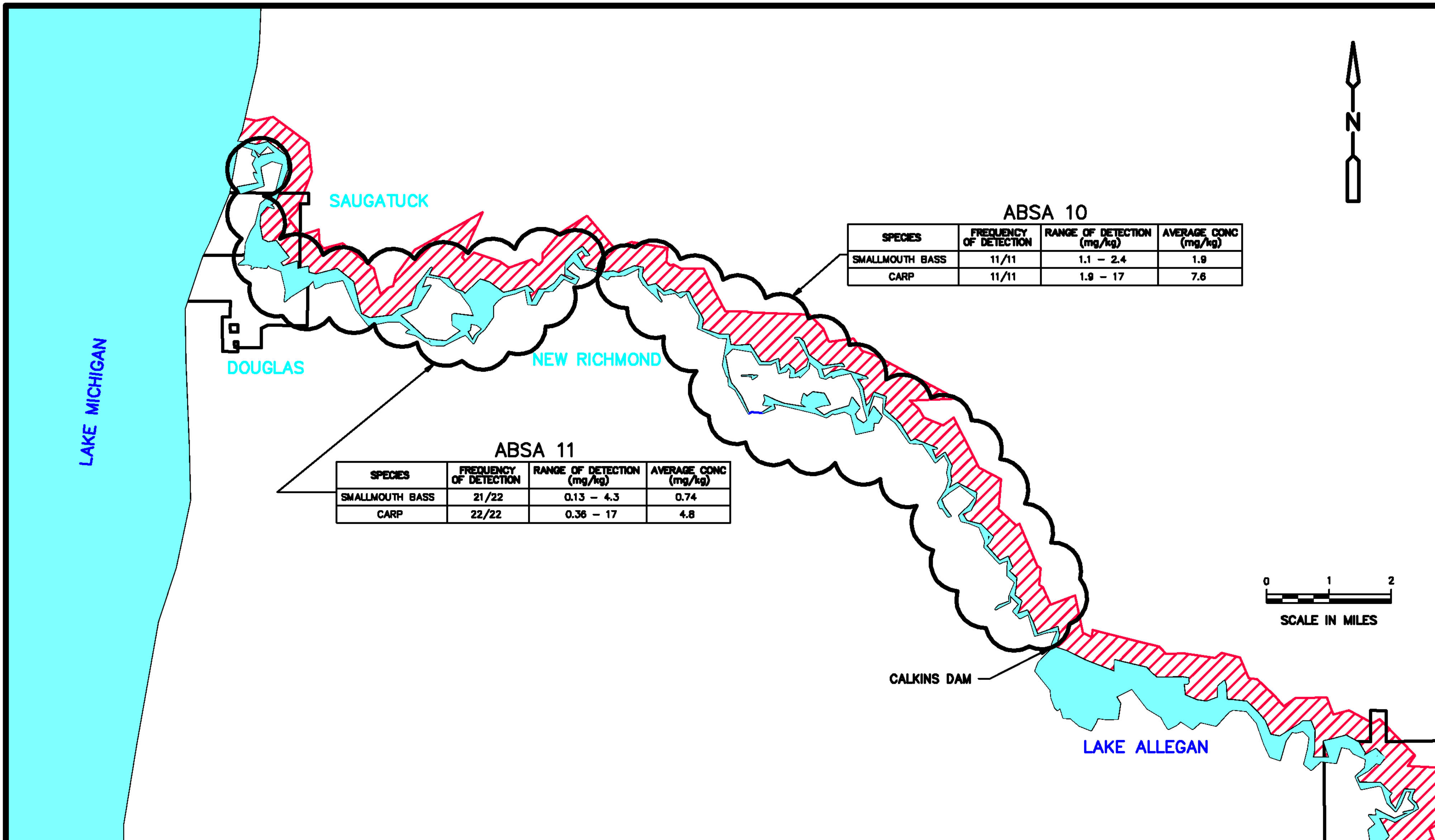
Figure No. 2-3



ABSA 10

SPECIES	FREQUENCY OF DETECTION	RANGE OF DETECTION (mg/kg)	AVERAGE CONC (mg/kg)
SMALLMOUTH BASS	11/11	1.1 – 2.4	1.9
CARP	11/11	1.9 – 17	7.6

ABSA 11

SPECIES	FREQUENCY OF DETECTION	RANGE OF DETECTION (mg/kg)	AVERAGE CONC (mg/kg)
SMALLMOUTH BASS	21/22	0.13 – 4.3	0.74
CARP	22/22	0.36 – 17	4.8

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KALAMAZOO RIVER HUMAN HEALTH RISK ASSESSMENT
ABSA 10 & 11

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Figure No. 2–4

While PCB concentrations in turtles caught later in the season may be higher, detected PCB concentrations in turtles were generally less than those detected in fish. For example, total PCBs ranged from 0.13 to 5.8 mg/kg in smallmouth bass fillets and 0.1 to 17.2 mg/kg in carp fillets compared to 0.11 to 8.1 mg/kg in turtle tissue. Further, turtle ingestion rates are assumed to be less than fish ingestion rates, therefore, risks associated with turtle ingestion are likely to be less than those associated with fish ingestion. Lack of representative turtle data represents a data deficiency that could result in the underestimation of risks and hazards, and prevents defensible quantification of possible human health impacts.

2.1.3 Waterfowl

A limited number of waterfowl samples have been collected from the Kalamazoo River. In 1985, the U.S. Fish and Wildlife Service (USFW) collected 12 mallards, 2 wood duck, 1 Canada goose, and 1 blue-winged teal from Otsego City Impoundment, Trowbridge Impoundment, Allegan State Game area, and Saugutuck. Samples were analyzed for Aroclor 1260. These data are reported in Kalamazoo River Action Plan (Michigan Department of Natural Resources [MDNR] 1987). Detected concentrations ranged from 0.60 mg/kg in an immature mallard from Saugatuck to 4.8 mg/kg in an adult mallard from Otsego City Impoundment. Also in 1985, the USFW collected 2 mallards from the Kalamazoo River and 9 mallards from the Potawatomie Marsh. Samples were analyzed for total PCBs, which were detected in one sample at a concentration of 0.29 mg/kg. These data sets are included in Appendix C.

Based on the age of these data sets and their limited nature, these data cannot support defensible estimates of risks or hazards to hunters. This exposure pathway is, however, considered important for the Kalamazoo River area, since hunting waterfowl is a widespread recreational activity. Additional data are needed to adequately evaluate risks to this population. This pathway may be evaluated in an addendum to this HHRA.

2.1.4 Floodplain Soil/Sediment

The Kalamazoo River has been dammed in five places within the API/PC/KR. From the 1950s through the 1970s the paper companies discharged PCB contaminated effluent to the Kalamazoo River. Impoundments created by these dams acted as settling basins for PCB wastes. Three of these dams, Plainwell, Otsego, and Trowbridge, and their impoundments, were acquired by the state of Michigan in the late 1960s. The impoundments were drained in the early 1970s although the dams were not completely removed, thereby exposing sediments previously overlain by river water. These exposed sediments are part of the API/PC/KR site.

The exposed floodplain soils in the vicinity of the former Plainwell, Otsego, and Trowbridge dams cover approximately 61, 37, and 346 acres, respectively. Data from samples obtained from the top 0 to 6 inches soils were evaluated in this HHRA, because this horizon is most accessible to people living nearby. Table 2-3 summarizes floodplain data for these three areas. Figure 2-5 illustrates areas of exposed floodplain soils. The highest PCB concentrations were detected in the Plainwell area, followed by Trowbridge and Otsego. The frequency of detection was above 80 percent for all areas indicating that deposition of contamination was widespread. Due to the proximity of residential areas to these areas of exposed sediment, exposures associated with floodplain sediment/soil are quantitatively evaluated in the HHRA.

Table 2-3 Floodplain Soil Data, API/PC/KR Site

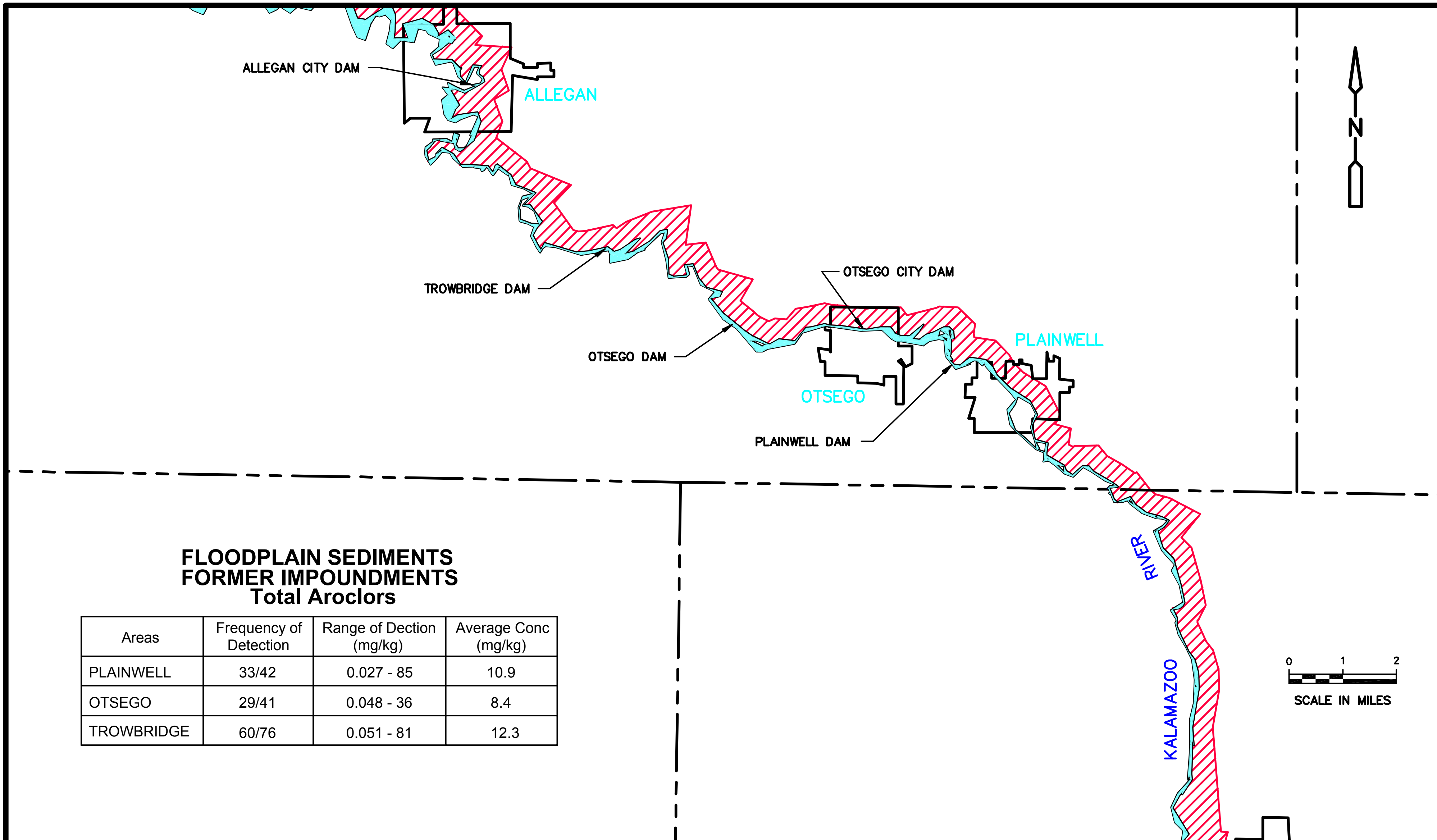
	Total Aroclor			
Area	**Frequency of Detection**	**Range of Detection (mg/kg)**	**Average Conc. (mg/kg)**	**Maximum Conc. (mg/kg)**
Plainwell	33/42	0.027 - 85	10.9	85
Otsego	29/41	0.048 - 36	8.4	36
Trowbridge	60/76	0.051 - 81	12	81

2.1.5 River Sediment

Over 1,000 instream cores have been collected from 151 transects in the Kalamazoo River. Five to nine samples were collected from each transect and 365 samples were analyzed for PCBs, total organic carbon, grain size, and percent solids. These data were collected as part of the Remedial Investigation and were reported in Draft Technical Memorandum 10 – Sediment Characterization/Geostatistical Pilot Study (BB&L 1994a). Note that to date not all sediment cores have been analyzed. Sediment data used in this assessment were those available at the time the report was prepared.

The major potential exposure pathway associated with near and in-stream sediments is indirect, involving first uptake of PCBs into fish, then consumption of these contaminated fish by anglers. Since adequate fish tissue data were available for use in the HHRA, no modeling of transport of PCB in the food chain was necessary for the assessment of risks or hazards for this pathway. Sediment data were, however, used along with data from fish tissues, to estimate Biota Sediment Accumulation Factors (BSAFs). These factors were critical to the development of possible risk-based remediation goals based on fish consumption.

Based on an evaluation prepared by the Michigan Department of Community Health (MDCH), and a review of data and risks associated with sediment exposures at the Lower Fox River site, direct contact exposure to instream sediments during recreational activities is not an important means of exposure to PCBs. The Health Consultation for Allied Paper/Portage Creek/Kalamazoo River (MDCH 1997), prepared under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR) (July 2, 1997), notes that "moist sediments might adhere more strongly to skin than drier soil, but river water would tend to wash the sediments off before the soiled skin reaches the mouth or food." Further, the report concludes that "based on the PCB concentrations reported in the sediment and water of the Kalamazoo River, and considering the frequency of exposure to the sediments, and limited absorption of PCBs from soils, there is no need to restrict access to the sediment and water of the Kalamazoo River."



FLOODPLAIN SEDIMENTS
FORMER IMPOUNDMENTS
Total Aroclors

Areas	Frequency of Detection	Range of Dection (mg/kg)	Average Conc (mg/kg)
PLAINWELL	33/42	0.027 - 85	10.9
OTSEGO	29/41	0.048 - 36	8.4
TROWBRIDGE	60/76	0.051 - 81	12.3

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KALAMAZOO RIVER HUMAN HEALTH RISK ASSESSMENT
FLOODPLAIN SEDIMENTS

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Figure No. 2-5

These considerations indicated that exposure to instream sediments is not considered an important exposure pathway. Such exposures are not further evaluated in this HHRA.

2.1.6 Surface Water

Surface water concentrations of PCBs have been reported in Draft Technical Memorandum 16 – Surface Water Investigation (BB&L 1995a) and the description of the Current Situation (BB&L 1992). Maximum and central tendency (median) PCB concentrations reported in surface water in the most recent of these reports are 0.000071 µg/L and 0.000025 µg/L, respectively. All detected concentrations are below drinking water maximum contaminant levels (MCLs) published by EPA. The MCL for PCBs is 0.5 micrograms per liter (µg/L). The Kalamazoo River is not used for drinking water, but incidental ingestion could occur during swimming, wading, or similar activities. The quantity of water consumed during swimming (50 milliliters/hour, which is a typical swimming event) is estimated to be much less than that consumed when water is used for drinking (2 liters/day) (EPA 1989). MDEQ has established a surface water criterion for PCBs of 0.00012-µg/L protective of wildlife and a criterion of 0.000026-µg/L protective of human health. Water concentrations detected in the Kalamazoo have exceeded the criterion protective of human health; however, exposures via direct contact and incidental ingestion of surface water are not considered significant pathways and were not further evaluated in this HHRA. Further rationale for elimination of these pathways is presented in Section 3.2.

2.1.7 Air

No air data have been collected in the immediate vicinity of the River or exposed floodplain soils. An air investigation was conducted at the Willow Boulevard/A-Site Operable Unit (OU) located in Kalamazoo Township, Michigan. As reported in Draft Technical Memorandum 5 – Willow Boulevard/A-Site Operable Unit[1]: Results of the Air Investigation, the air investigation involved collection of 15 samples over a 3-month period from 5 perimeter samplers and 2 background location samplers. Objectives of the air investigation were to (1) identify the highest representative PCB concentrations expected for adjacent or nearest public access and residential locations, and (2) provide data necessary to determine whether significant quantities of PCBs are migrating from the operable unit via the air pathway.

Sampling of both particulate phase and vapor phase PCBs according to standard EPA protocols was conducted using glass-fiber filters and high-volume polyurethane foam (PUF) cartridges, respectively. Arithmetic average concentrations of PCBs ranged from 0.00049 µg/m^3 to 0.0029 µg/m^3; this range is below the secondary risk screening level of 0.02 µg/m^3 developed by the MDEQ Air Quality Division. At the time of sampling, the Willow Boulevard/A-Site OU was partially vegetated. Conditions have

1 This OU is the site of two locations where PCB-containing wastes were placed adjacent to the river and within the floodplain.

since changed and the site is no longer vegetated but is covered with a temporary soil cover.

These data are not appropriate for evaluating risks and hazards associated with exposures to particulates or volatile emissions from the river or exposed floodplain soils. Instead of using site data, quantitative estimates of particulate and volatile emission from the exposed floodplain soil were developed using algorithms adapted from Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites (ASTM 1995). Exposures to PCBs in air based on these estimates are used in quantitative risk estimates for both residential and recreational exposure scenarios. Exposures to volatile emissions from surface water have not been evaluated. In the absence of air data or air modeling to characterize this exposure pathway, overall site risks are likely to be underestimated.

Section 3
Exposure Assessment

Exposure assessment evaluates sources of contaminants in the API/PC/KR site, transport of contaminants to areas with human activity, and exposure to contaminants in these areas via inhalation, ingestion, and dermal contact. Whether an exposure occurs, and its magnitude and nature, depend on characteristics of the site. In this section, the character of the API/PC/KR site is described with a focus on those aspects most important for evaluating possible exposure to PCBs (Section 3.1). Subsequently, the potential for various exposure pathways[1] to cause human health impacts are analyzed, and means to quantitatively estimate health risks and hazards are developed.

3.1 Site Description

The API/PC/KR site is located in a moderately densely populated area. The site is located within the floodplain of the Kalamazoo River, a Class A water body and used for swimming, boating, and fishing. No restrictions against development along the river exist for areas outside of the 100-year floodplain. Land use along the river includes urban commercial and industrial; urban, suburban, and rural residential; agricultural; and recreational (MDPH 1991).

In addition to fishing and boating, recreational activities identified by the MDNR along the Kalamazoo River include:

- Canoeing
- Picnicking
- Mushroom and berry picking
- Wild food gathering
- Sightseeing/wild animal observation
- Bird watching

The primary source of contamination at the site is PCB residuals that were discharged into the river system by several paper mill facilities located upstream. In the de-inking phase of recycling paper fibers, specialty inks containing PCBs were liberated. Much of the dewatered paper waste was disposed of in landfills and sludge disposal areas located on the banks of the river. Erosion from these facilities, as well as direct discharge of millions of gallons per day of effluent into the river, has resulted in an estimated mass of over 29,300 kg of PCBs in instream sediments, and 24,500 kg of PCBs in exposed sediments at three former improvements (BB&L 2000).

The site contains six dams, three of which are owned by the MDNR and three that are owned by municipalities and private entities. These dams (in a downstream order)

1 An exposure pathway consists of a source of contamination, a release/transport mechanism, a point of contact with contamination, and a route of exposure (inhalation, ingestion, or dermal contact) (see Section 3.2).

are: Plainwell Dam, Otsego City Dam, Otsego Dam, Trowbridge Dam, Allegan City Dam, and Caulkins Dam on Lake Allegan. The Plainwell, Otsego, and Trowbridge dams are the three MDNR dams. During the time when these dams impounded water, PCB-contaminated sediments were deposited in the impoundments. When the superstructures of these dams were removed in 1986 and the water level was lowered to the dam sill, most of the deposited contaminated sediments were exposed in the floodplain. These exposed sediments are continuously being eroded into the Kalamazoo River and constitute a continual source of PCBs to the river system. The largest acreage of exposed sediments is behind the Trowbridge Dam. Residential properties are found immediately adjacent to the exposed sediments behind the Trowbridge and Otsego Dams. In some areas, the gray paper residual waste can be observed in the backyards of residential homes along the river. Additionally, the construction of a golf course behind the Trowbridge impoundment occurred on top of and immediately adjacent to exposed sediments containing paper residual waste. Established gardens have been observed in the former impoundment area behind Otsego Dam.

These MDNR-owned dams, along with the Caulkins Dam impounding Lake Allegan, have been identified as areas where local anglers frequently catch fish in the Kalamazoo River. Attractive habitat for fish near the dams attracts the anglers observed fishing in these stream reaches. Some fishing locations have been established on exposed floodplain sediments. In addition to attracting anglers, the three MDNR impoundments also attract waterfowl hunters, as evidenced by the duck blinds observed in the backwaters behind the remaining dam structures.

Floodplain and river sediments are both transport and exposure media. That is, sediments (instream and floodplain) are continuously entrained in and deposited from the water column, causing redistribution of PCBs in the riverine system. Further, some PCBs may become dissolved in surface water or entrained in air. In addition, sediments are a source for PCBs in fish, turtles, and probably waterfowl, and a potential source of exposure to residents and recreationalists living near or visiting areas with exposed contaminated sediments. For purposes of this evaluation, residents who live near the exposed floodplain soils were considered the most highly exposed individuals for direct contact exposure pathways. Risk and hazard quotient estimates for these individuals will serve as a conservative representation of risks and hazards to individuals that frequent the river.

Exposure routes either directly to the river and floodplain soil, or to secondary exposure media (surface water and air), include ingestion, sediment or soil, and surface water; dermal contact with sediment or soil and surface water; and inhalation of particulates and / or vapor emissions from exposed sediments.

Importantly, sediments are also a source of PCBs in fish tissues. Anglers, both recreational and subsistence, may be exposed to significant levels of PCBs via ingestion of fish taken from contaminated reaches of the river. In many assessments of

PCB contamination in river systems, consumption of contaminated fish has resulted in the highest estimates of exposure and health risk. Significant further evaluation of possible exposure of anglers and their families is provided in a later subsection. In particular, the existence and potential for exposure for subsistence anglers is characterized in Section 3.3.1. Subsistence anglers are those individuals who derive a large portion of their total dietary protein from consumption of locally caught fish.

Recreational and subsistence anglers, recreational users of the river for purposes other than fishing, and residents who may live near or on the river, were considered in the HHRA. For each of the populations, an exposure scenario was developed. An exposure scenario defines a particular manner in which people are exposed to contamination. An example of an exposure scenario includes: 1) ingestion of fish by subsistence anglers; and 2) ingestion of, dermal contact with, and inhalation of particulates and vapors from floodplain soil by nearby residents. Some of the possible exposure scenarios for the API/PC/KR site were evaluated quantitatively, i.e., numerical estimates of cancer risks and noncancer hazards were developed. Some of the possible exposure scenarios were evaluated qualitatively, i.e., a discussion of the significance of a particular pathway or adequacy of the data to evaluate the pathway was provided.

3.2 Determination of Exposure Pathway Significance

Many exposure pathways exist at most sites with significant chemical contamination. However, only a subset of these pathways, in almost all cases, might result in estimated risks high enough to warrant action to reduce exposures. In the following subsections, exposure pathways at the API/PC/KR site are identified that could result in risks above levels of concern.

3.2.1 General Considerations

Researchers have investigated the role of various environmental pathways of exposure to contaminants in the Great Lakes. Several multimedia studies indicated that most cases of human exposure (80 to 90 percent) to chlorinated organic compounds occur through the food pathway. A more recent multimedia study supports these findings and indicates that the primary pathway of exposure to PCBs is from fish consumption (Birmingham, et al. 1989; Newhook, et al. 1988; Fitzgerald, et al. 1996). Pathways involving ingestion of biota including fish and waterfowl were determined to warrant quantitative evaluation for the API/PC/KR site. However, as discussed in Section 2, data are insufficient to support quantitative analysis of exposures and risks to hunters who take and ingest waterfowl from the API/PC/KR site. Potential human health impacts for the hunter population remains a potentially significant source of uncertainty in this risk assessment.

During hunting or fishing activities, contact with river surface water and sediment may occur. Contact with surface water and sediment may also occur during other recreational activities such as swimming and boating. In general, contact with sediment and surface water does not result in significant risks or hazards. This assumption is consistent with the findings presented in *Health Consultation for Allied Paper/Portage Creek/Kalamazoo River* (MDCH 1997). In that document, it is stated that "moist sediments might adhere more strongly to skin than drier soil, but river water would tend to wash the sediments off before the soiled skin reaches the mouth or food." In addition, the quantity of water consumed during swimming has been estimated to be significantly less than that consumed when water is used for drinking water (50 milliliters/hour, which is a typical swimming event versus 2 liters/day) (EPA 1989, 1992). For this reason, the ingestion of surface water is not considered a significant pathway.

To confirm that contact with instream sediment and surface water would not result in significant risks or hazards for the API/PC/KR site, site data were compared to data from the Lower Fox River in Wisconsin. Exposure conditions at the two sites are very similar in that both sites have active recreational populations involved in fishing, hunting, and boating and residential populations living on or near the site. An HHRA conducted for the Lower Fox River evaluated numerous pathways and found that only the following four exposure pathways were associated with significant risks or hazards:

- Ingestion of fish by subsistence anglers
- Ingestion of fish by recreational anglers
- Ingestion of waterfowl by hunters
- Inhalation of contaminants in outdoor air from volatizing from surface water by nearby residents

Significant risk is defined by MDEQ as a level above a cancer risk threshold of 1 in 100,000 excess lifetime cancer risk, and significant hazard of noncancer adverse health effect is indicated by a hazard quotient greater than 1.0.

The first two of these pathways were quantitatively evaluated for the API/PC/KR site. Additional data are needed, however, to adequately evaluate ingestion of waterfowl by hunters and volatilization from surface water to outdoor air.

Exposure pathways involving direct contact with surface water and instream sediment, i.e., the recreational wader or swimmer, were not associated with significant risks or hazards for the Lower Fox River. Drinking water ingestion was evaluated for the Lower Fox River, but water from the Kalamazoo River is not used for drinking water; therefore, this pathway is not relevant to the site.

3.2.2 Quantitative Comparisons with Lower Fox River

Table 3-1 presents upper-bound and average concentrations of PCBs in sediment, surface water, fish, and waterfowl at the Lower Fox River and API/PC/KR sites.

Upper-bound and average concentrations for all abiotic and biotic media are higher from the API/PC/KR site than from the Lower Fox River site.

Relative risks and hazards for the two rivers can be estimated by scaling estimates for the Kalamazoo River using the Lower Fox River as a baseline. Scaling assumes that exposure assumptions for recreational swimmers, waders, sport anglers, and subsistence anglers are comparable at the two sites. These scaling assumptions are justified in the present case because of the substantial similarities of the two river environments.

Table 3-1 Comparison of Total PCB Exposure Point Concentrations of Lower Fox River and Kalamazoo River API/PC/KR Site

	Upper Bound (1)		Central Tendency (2)	
Medium	**Fox River (3)**	**Kalamazoo (4)**	**Fox River (3)**	**Kalamazoo (4)**
Fish Tissue (mg/kg) (Fillet data)	4.6 (6)	17.34 (max-carp) 5.8 (max-smb)	3.0 (6)	7.6 (carp) 1.9 (smb)
Waterfowl Tissue (mg/kg)	1.23 (7)	4.8 (max)	0.54	1.7
Surface Water (mg/L)	1.49E-04 (8)	7.1E-05 (max)	4.42E-05	2.5E-05 (median)
Sediment (mg/kg)	3.75 (9) 710 (12)	156 (max-ABSA 7) (10) 13.6 (U95, ABSA 7)	3.69 (11) 20 (12)	3.7 (5)

(1) Upper-bound measure concentrations - lower of the 95% UCL on the arithmetic mean or the maximum detected concentration.
(2) Central Tendency = the arithmetic mean except for Kalamazoo surface water which is median value.
(3) Lower Fox River data from ThermoRetec, 2001.
(4) Kalamazoo River data derived from following sources:
  Fish (BB&L 1995b; 1998)
  Waterfowl (MDNR 1987)
  Surface Water (BB&L 1995a)
  Sediment (BB&L 1994a)
(5) Average from ABSAs 3,4,5,6,7,8,9 as reported in CDM 1999 originally derived from BB&L 1994a.
(6) Upper-bound concentration is the maximum detected in fillet samples of walleye collected from the DePere to Green Bay reach in the 1990s. Central tendency concentration is average for carp collected in the same reach in the 1990s. The most common species sampled include walleye, carp, trout, and bass.
(7) Upper-bound concentration is the 95% UCL on the arithmetic mean of samples collected from Little Rapids to DePere reach.
(8) Upper-bound concentration is the 95% UCL on the arithmetic mean of surface water samples collected from the DePere to Green Bay reach. All water concentrations result from analyses of unfiltered samples.
(9) Upper-bound concentration is the 95% UCL on the arithmetic mean of samples collected from Little Lake Butte des Morts reach. Concentration is based on interpolated data. Note that some higher concentrations (710 max; 20 average mg/kg) were found in the DePere to Green Bay reach.
(10) For the Kalamazoo River site, ABSA 7 was chosen for the comparison because the maximum PCB concentration occurred in this reach of the river and because overall concentrations in this ABSA were relatively high. The average concentration in ABSA 7 (5.2 mg/kg) is about twice the sitewide average (2.4 mg/kg). Using ABSA 7 to represent the API/PC/KR site should provide a "worst case" for comparison with the Fox River.
(11) Highest average based on interpolated data from Little Lake Buttes des Morts reach.
(12) The higher value was calculated from the DePere to Green Bay reach.

When all exposure parameters for a population are held constant, risks and hazards are proportional to exposure concentrations. The ratio of media concentrations to risks or hazards for the Lower Fox can therefore be used to estimate risks or hazards associated with API/PC/KR media concentrations. Such scaled risks and hazards associated with exposure to upper-bound instream sediment and surface water are shown in Table 3-2. Even though PCB concentrations for surface water and most instream sediment in API/PC/KR were higher than the Lower Fox, exposure involving contact with these media would not result in risks or hazards that exceeded regulatory thresholds. A more complete description of the results of risk and hazard scaling are presented in Appendix D.

Table 3-2 Comparison of Calculated Fox River and Scaled Kalamazoo River API/PC/KR Site Risks and Hazards

		Fox River		Kalamazoo River	
Pathway	**Media**	**Calculated Risks**	**Calculated Hazards**	**Scaled Risks**	**Scaled Hazards**
Recreational Angler	Surface Water	1.7E-08 - 1.2E-07 (1)	1.0E-03 - 6.0E-03 (1)	1.2E-07 - 3.5E-07 (2)	2.2E-03 - 2.9E-02 (2)
	(ingestion, dermal contact)				
Subsistence Angler	Surface Water	2.4E-08 - 1.6E-07 (1)	2.0E-03 - 8.0E-03 (1)	2.8E-08 - 4.7E-07 (2)	5.4E-02 - 3.9E-02 (2)
	(ingestion, dermal contact)				
Recreational Swimmer	Surface Water	6.8E-08 (3)	1.4E-02 (3)	2.0E-07 (4)	4.1E-02 (4)
	(ingestion, dermal contact)				
	Sediment	8.7E-08 (3)	2.5E-02 (3)	5.8E-08 - 2.1E-07 (5)	1.7E-02 - 6.2E-02 (5)
	(ingestion, dermal contact)				
Recreational Wader	Surface Water	7.8E-09 (3)	2.0E-03 (3)	2.3E-08 (4)	9.8E-03 (4)
	(ingestion, dermal contact)				
	Sediment	1.9E-07 (3)	2.5E-02 (3)	1.3E-07 - 4.7E-07 (5)	1.7E-02 - 6.2E-02 (5)
	(ingestion, dermal contact)				

Scaled risks are calculated as FOX RIVER - RISK OR HAZARD * API/PC/KR - MEDIA CONCENTRATION ÷ FOX RIVER - MEDIA CONCENTRATION

Notes:
(1) Based on range of calculated cancer and noncancer risks associated with the average concentration and the upper-bound concentration (either 95% UCL or maximum).
(2) Based on scaled cancer and noncancer risks associated with the average concentration and the maximum concentration.
(3) Based upper-bound concentrations (either on 95% UCL or maximum). Based on concentrations of PCBs in Little Lake Butte des Morts.
(4) Based on maximum concentrations.
(5) Based on range of calculated cancer and noncancer risks associated with the average concentration and the 95% UCL.

3.3 Receptors

Recent data compiled through the ATSDR Great Lakes program indicate the following:

- Approximately 4.7 million people consumed Great Lakes' sport-caught fish within the past year
- Knowledge of and adherence to health advisories for sport-caught fish vary across different populations
- Advisory awareness is especially low in women and minority populations

- Fish are an essential component of the diets of minority and Native American populations; they consume fish that tend to have higher levels of contaminants, and their cooking practices increase their exposure to Great Lakes contaminants compared to recommended fish preparation techniques (Johnson 1998)

Further for the API/PC/KR site,

- Residences abut former impoundment areas, and some gray residuals from paper wastes have been observed in residential yards

- Evidence of recreational use is observed in former impoundment areas; including established gardens, trails, hunting blinds, and fishing spots

The above information, combined with the pathways analysis presented in Section 3.2, indicates that five receptor groups should be quantitatively evaluated in this HHRA for one or more pathways of exposure, including:

- Subsistence anglers
- Central Tendency Sport anglers
- High end sport anglers
- Nearby residents
- Recreationalists

3.3.1 Subsistence Anglers

Subsistence anglers are individuals who would not be able to meet their daily nutritional requirements if they could not supplement their diet with sport-caught fish. In a survey financed by the Michigan Great Lakes Protection Fund, *Michigan Sport Anglers Fish Consumption Study*, 1991-1992 (West 1993), a sample of 7,000 persons with Michigan fishing licenses was drawn and surveys were mailed in 2-week cohorts from January 1991 to January 1992. Respondents were asked to report consumption patterns during the proceeding 7 days. A response rate of 46.8 percent was reported with 2,681 surveys returned. Fish consumption rates were found to be higher among minorities, people with low income, and people residing in small communities.

Three subpopulations of subsistence anglers have been evaluated in several studies of the Great Lakes region:

- Low-income/minorities
- Native Americans
- Hmong

Out of a total estimated population of 329,912 in Allegan and Kalamazoo counties, West (1993) estimated a low income (<$25,000) population of 99,094, and a minority/low-income population of 9,022.

The MDCH conducted the Kalamazoo River Angler Survey and Biological Testing Study. This study, funded by the ATSDR, involved field surveys conducted from May to September 1994 and interviews of 938 anglers in Kalamazoo and Allegan Counties. Information on income level was not reported, though unemployment rates were reported. Unemployment rates for anglers in Allegan County (20.5 percent) and Kalamazoo County (17.4 percent) were higher than the overall unemployment rates for these counties (MDCH 2000b). Respondents were questioned on age, education, race (white, nonwhite), gender, smoking status, drinking status, weight change, and awareness of fish advisories.

Almost 4 percent of the Allegan County anglers reported that they fished for food only, while none of the Kalamazoo County anglers reported that they fished for food only. An additional 10.6 percent of all anglers responded that they fished for both food and recreation (MDCH 1998).

Allegan and Kalamazoo County public health agency staff conducted the interviews. Interviewers reported they were unable to interview Hmong anglers that have been observed fishing in the Lake Allegan area. At other Superfund sites, this segment of the population makes up a large component of the subsistence fishing population. Two key studies, *Hmong Fishing Activity and Fish Consumption* (Hutchinson and Kraft 1994) and *Fish Consumption by Hmong Households in Sheboygan, Wisconsin* (Hutchinson 1994) examined fishing activity and fish consumption rates in Green Bay, Wisconsin and Sheboygan, Wisconsin, respectively.

Native American anglers were not specifically targeted in the Kalamazoo Angler Survey although an early draft of the survey reported that 9 percent of 143 male respondents in Allegan County were Native American and 0.5 percent of 213 male respondents in Kalamazoo County were Native American. A number of studies have been conducted on fish ingestion rates of Native American populations in Alaska (Wolfe and Walker 1987); the Columbia River Basin (CRITFC 1994); Wisconsin (Peterson, et. al 1994; Fiore 1989); and the St. Lawrence River (Fitzgerald 1995, 1996).

The Lower Fox River HHRA evaluated four different subsistence fishing scenarios:

- Low-income, minority (based on West 1993 data)
- Native American angler (based on Peterson 1994 and Fiore 1989)
- Hmong (based on Hutchinson and Kraft 1994)
- Hmong (based on Hutchinson 1998)

The overall ingestion rates and exposure frequencies for the low-income, minority angler were the highest of these four scenarios; risks and hazards for the low-income, minority angler were also the highest of these four scenarios. For this reason, and the existence of this subpopulation within and near the API/PC/KR site, the subsistence scenario used for the site is based on a low-income, minority population.

3.3.2 Sport Anglers

Fishing is a popular recreational activity on the Kalamazoo River. Because multimedia studies have indicated that most cases of human exposure to chlorinated organic compounds (80 to 90 percent) occur through the food pathway, and the primary pathway of exposure is from fish consumption, risks and hazards to the sport angler population were evaluated in this HHRA.

The Kalamazoo River is a favorite fishing site for sport anglers and subsistence fishermen. Smallmouth bass are a favorite target in the Kalamazoo area. Additionally, the downstream reaches of the Kalamazoo River below Caulkins Dam is known for steelhead and salmon fishing. The Kalamazoo River is also popular for catching carp, panfish, channel catfish, and sucker species (personal communication with Jim Dexter, MDNR).

Anglers have been observed fishing in the vicinity of the three MDNR dams on a regular basis, and the Trowbridge Dam has a boat launch ramp used by anglers and duck hunters to access the backwater areas behind this impoundment. Fishing is limited on Lake Allegan due to poor habitat, and most fishing is restricted to channel catfish, carp, and occasional panfish.

Two populations of sport anglers were evaluated to provide some indication of the possible range of exposures and risks. The central tendency sport angler was evaluated to provide an indication of average exposures in the angler population. The high end sport angler was evaluated to provide an upper-range estimate characteristic of avid sport anglers. Assumptions regarding fish ingestion rates, reduction of PCBs due to cooking fish, and portion of fish caught from the contaminated area are different for the central tendency and high end sport anglers. These assumptions are further discussed in Section 3.5.2.

3.3.3 Nearby Residents

Urban, suburban, and rural residential populations exist along stretches of the Kalamazoo River. Development within the 100-year floodplain is restricted; however, despite inclusion of 80 miles of the Kalamazoo River in the study area of the API/PC/KR National Priority List site, residential, commercial, and recreational development along the river outside this floodplain has proceeded unrestricted.

In particular, residential development has occurred adjacent to exposed floodplain soil in the vicinity of the former Trowbridge, Otsego, and Plainwell dams. These areas are completely accessible to the public and, in essence, form the "backyard" for some residents. For these reasons, a residential scenario was evaluated for direct exposure in the three floodplain areas.

3.3.4 Recreationalists

Some parts of the former impounded areas abut neighborhoods and residential property and are completely accessible to children and adults. Other areas are relatively less accessible to children but are accessible to adults who may engage in recreational activities such as bird watching, picnicking, and hunting. In particular, the former impoundment areas near the Trowbridge, Otsego, and Plainwell Dams are accessible for these activities and are large enough to attract frequent visitors. For these reasons, a recreational scenario was evaluated for direct exposure in the floodplain areas.

3.4 Exposure Pathways Summary

Figure 3-1 presents a site conceptual model for the API/PC/KR site. The conceptual model identifies potential receptors and exposure pathways. The model is a graphic summary to the preceding pathways and receptor analyses.

As discussed above, exposure pathways are the mechanisms by which people are exposed to chemicals from a site. A pathway is the route between a contaminated medium and a receptor. Some exposure pathways were evaluated qualitatively; i.e., a discussion of the relative insignificance of these pathways was provided to support eliminating them from further consideration. Some pathways were evaluated quantitatively; i.e., numerical estimates of cancer risks and noncancer hazards were generated. Receptors and exposure pathways quantitatively evaluated for this site include:

- Sport anglers - fish ingestion
- Subsistence anglers - fish ingestion
- Residents living adjacent to exposed floodplain soil - incidental ingestion of, dermal contact with, and inhalation of particles and the volatile fractions of floodplain soil
- Recreationalists exposed to floodplain soil - incidental ingestion of, dermal contact with, and inhalation of particles and the volatile fractions of floodplain soil

The Kalamazoo River is used for swimming, boating, and fishing. While a fish consumption advisory has been issued by the MDCH, the advisory is not legally binding, and local health officials and other local government representatives reported observing frequent fishing activity within the contaminated zone of the river (MDCH 1999). Subsistence level consumption of fish from the river cannot be ruled out.

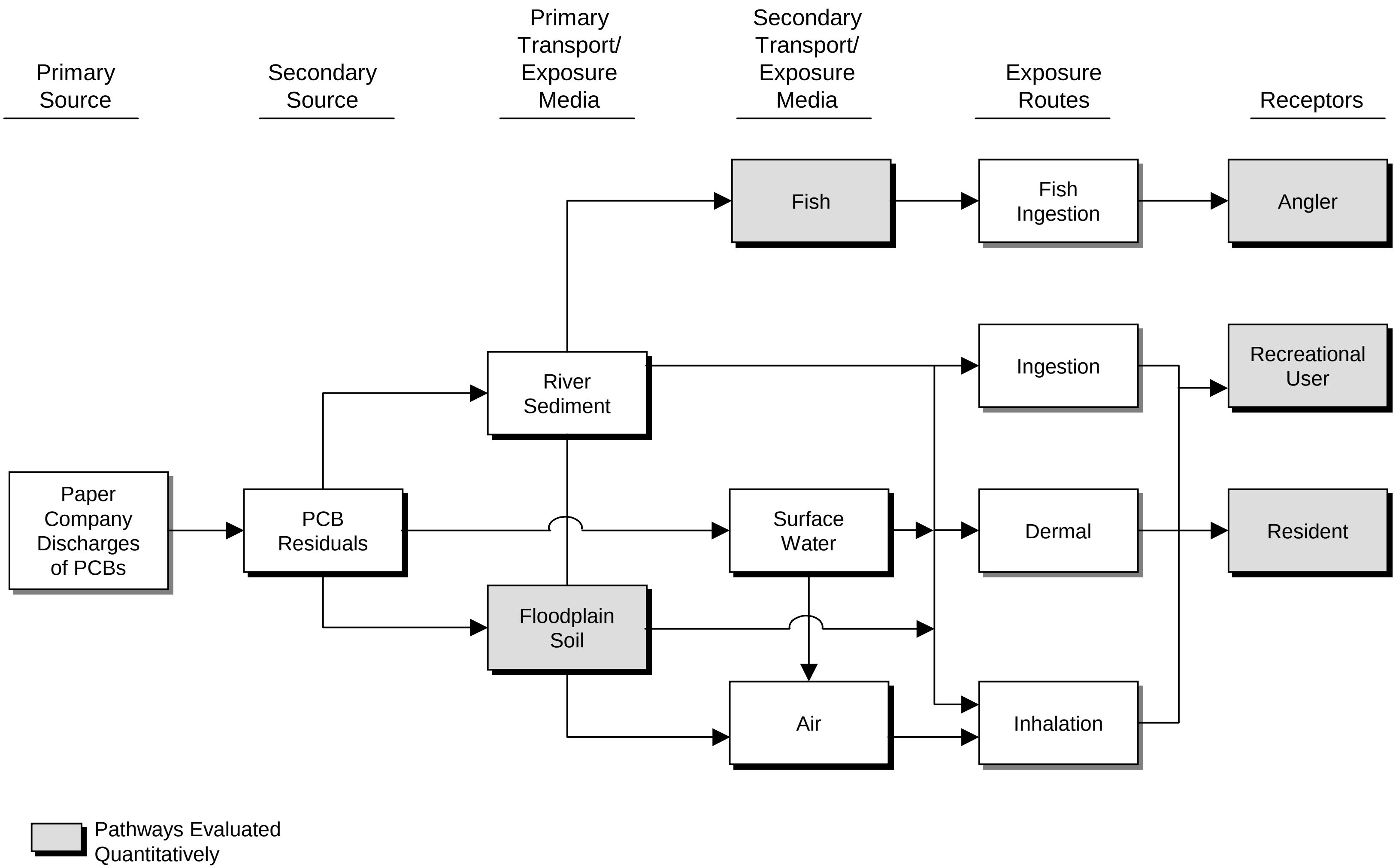


Figure 3-1
Site Conceptual Model
API/PC/KR Site

CDM

Fish ingestion is the primary exposure pathway for the API/PC/KR site. PCBs bioaccumulate in the food chain. Ingestion of fish is likely to result in higher exposures and greater risks than direct exposures to sediment and surface water containing PCBs. Exposure to floodplain soils is also considered to be significant, and was evaluated quantitatively due to the close proximity of residential areas to the floodplain soils.

Residents live immediately adjacent to former impoundment areas and may frequently use these areas much as other residents use their backyards. For example, large, well-maintained vegetable gardens have been found in the impoundments. Further, gray paper waste residual materials have been observed in residential yards, suggesting that exposures could take place in some areas outside the floodplain.

The recreational user of the river is likely exposed to instream sediment and surface water during swimming or wading activities or to floodplain soil, including soils near the three former MDNR impoundments, during other recreational activities.

A number of recreational activities are undertaken along the Kalamazoo River including hunting, picnicking, mushroom and berry picking, and bird watching. Hunting seasons for the following animals draw recreationalists to the banks of the Kalamazoo from September through May: rabbit (September 15 through March 31); deer (archery: October 1 through November 14; firearm: November 15 through 30; muzzle-loading: December 10 through 19); grouse (September 15 through November 14 and December 1 through January 1); squirrel (September 15 through January 1); turkey (October 4 through November 9 and April 12 through May 31); woodcock (September 25 through November 8); fox (October 15 through March 1) and raccoon (October 1 through January 31). Exposure to floodplain soil is considered significant for both nearby residents and recreationalists, therefore recreational exposures to floodplain soils was evaluated quantitatively.

The significance of exposures to instream sediment and surface water is considered low due to the relatively low surface water and sediment ingestion rates associated with swimming and wading, the low solubility of PCBs in water, and limited absorption through the skin.

Two exposure pathways have not been fully evaluated in this HHRA due to a lack of data. The Kalamazoo River watershed area is used extensively to hunt duck and other waterfowl. A limited and potentially outdated data set exists to quantitatively evaluate this pathway. It is recommended that additional data be collected to determine the potential risks to hunters who ingest duck and other waterfowl.

Volatilization of PCBs from surface water to air has been evaluated in previous risk assessments conducted on sites similar to the API/PC/KR. In the *Baseline Human Health and Ecological Risk Assessment for the Lower Fox River, Wisconsin* (ThermoRetec Consulting Corporation 1999), risk estimates for this exposure pathway were above the EPA risk thresholds. Maximum and average concentrations in the Kalamazoo

River are higher than those detected in the Fox River, indicating that risks may be higher for the API/PC/KR site. This pathway may be evaluated in an addendum to this HHRA.

3.5 Exposure Assumptions

To estimate risks and hazards to populations, the magnitude and nature of exposures to chemicals must first be characterized. Information and assumptions on frequency of exposure, duration of exposure, and consumption rates are used to estimate exposures received by people who eat contaminated fish or who live, work, or play on contaminated soils. These exposure assumptions result from the evaluation of surveys and studies conducted on the behaviors of individuals and groups such as subsistence and sport anglers, and residents. Some exposure assumptions are also based on EPA and MDEQ guidance.

3.5.1 Generalized Assumptions

Tables 3-3, 3-4, and 3-5 summarize the exposure assumptions for sport and subsistence anglers, residents near floodplain soil, and recreationalists respectively. Many exposure assumptions for anglers are taken from the results of angler surveys specific to the Kalamazoo River area. These assumptions are discussed in more detail in Section 3.5.2. Many other assumptions are more generic and are adopted from regulatory guidance. Exposure assumptions for exposure frequency and duration from recreational exposures are based on professional judgment.

Body weight is a standard exposure factor for adult males specified in the Exposure Factors Handbook (EPA 1997). Soil ingestion rate, dermal contact rate, and inhalation rate are age-adjusted rates for individuals from 1 to 31 years of age. These exposure assumptions, along with exposure frequency and duration for residential exposures, are given as standard default assumptions for the residential scenario in Environmental Response Division Interim Operational Memorandum #18: Generic Soil Direct Contact Criteria (MDEQ 2000). Ingestion of soil by nearby residents is assumed to take place year-round because soil from outdoor sources can be entrained into the indoor environment as indoor dust.

Ingestion of soil by recreationalists is assumed to occur only on days when they are on the site. Dermal exposure is limited to periods during which there is no snow cover preventing contact (MDNR 1995). The number of days of exposure per year is based on the assumption that recreational exposure will be frequent because of the proximity of recreational and residential areas. The number of years of exposure is based on a typical upper-range estimate of time at one residence (EPA 1997), reduced to exclude the youngest children who are not expected to wander far from their yards on a regular basis.

Table 3-3 Exposure Assumptions for Sport and Subsistence Anglers API/PC/KR Site

Assumption	Central Tendency Sport Angler	High End Sport Angler	Subsistence Angler	Reference
Body Weight	70-kg	70-kg	70-kg	EPA 1997
Fish Ingestion Rate	0.015 kg/day (24 meals/year)	0.078 kg/day 125 meals/year	0.11 kg/day (179 meals/year)	West 1993
Fraction from Contaminated Source	1.0	0.5	1.0	Site-Specific
Exposure Frequency	365 days/year	365 days/year	365 days/year	EPA 1997
Exposure Duration	30 years (cancer) 30 years (noncancer) 2-7 years (reproductive)	30 years (cancer) 30 years (noncancer) 2-7 years (reproductive)	30 years (cancer) 30 years (noncancer) 2-7 years (reproductive)	EPA
Species	Smallmouth bass (100%) and Smallmouth bass/Carp (76%) (24%)	Smallmouth bass (100%) and Smallmouth bass/Carp (76%) (24%)	Smallmouth bass (100%) And Smallmouth bass/Carp (76%) (24%)	Site-Specific
Reduction Factor	50%	50%	50%	Zabik 1995
Relative Absorption Efficiency	100%	100%	100%	ATSDR 1996

Table 3-4 Exposure Assumptions for Residents Near Floodplains Soils API/PC/KR Site

Assumption	Resident	Reference
Soil Ingestion	114 mg-yr/kg-day (age adjusted)	MDNR 1995
Dermal Contact Rate	353 mg-yr/kg-day (age adjusted)	MDEQ 2000
Inhalation Rate	7.52 m3-yr/kg-day (age adjusted)	MDNR 1995
Age	1-31 years	EPA 1997
Fraction from Contaminated Source	1.0	Site-Specific
Exposure Frequency	350 days/year (ingestion) 245 days/year (dermal)	MDNR 1995
Exposure Duration	30 years (cancer) 30 years (noncancer) 2-7 years (reproductive)	EPA 1997
Relative Absorption Efficiency	0.14	EPA 1998a

Table 3-5 Exposure Assumptions for Recreationalists on Floodplain Soil

Assumption	Resident	Reference
Soil Ingestion	2.8 mg-yr/kg-day 47 mg-yr/kg-day 34 mg-yr/kg-day	MDNR 1995
Dermal Contact Rate	85 mg-yr/kg-day 61 mg-yr/kg-day	EPA 1997b
Inhalation Rate	1.37 m3-yr/kg-day 1.9 m3-yr/kg-day	EPA 1997b
Age	6 - 31 years	Site-Specific
Fraction from Contaminated Source	1.0	Site-Specific
Exposure Frequency	128 days	Site-Specific
Exposure Duration	2-7 years (reproductive) 24 years (immunological) 24 years (cancer)	EPA 1997b EPA 1997b EPA 1996
Relative Absorption Efficiency	0.14	EPA 1998

For reproductive effects, an exposure duration of 2 to 7 years is used based on toxicity studies that indicate adverse effects on the fetus such as reduced birth weight, reduction in gestational age, and reduced head circumference. Two to seven years is a conservative estimate based on an assumption that continuing exposure over a fairly short time period leading up to conception could result in toxic levels of PCBs in the developing embryo/fetus. In practice, the exposure duration term for noncancer health effects appears in both the numerator and denominator of exposure equations. Thus, when all other parameters are kept constant, changing the exposure duration does not alter hazard estimates. The short exposure duration assumption therefore reflects a qualitative judgment of potential for health effects and does not affect calculated hazards. Section 4 of this report describes the toxicity of PCBs in more detail.

For recreationalists, unitized contact rates are not provided in MDEQ guidance. Soil ingestion for the recreationalist is based on 100 milligrams ingestion for each day of exposure. The unitized ingestion rate is derived as follows:

$$\mathbf{100\ mg\ /\ day * exposure\ duration\ /\ 70\ kilograms\ bodyweight}$$

The dermal contact rate for recreationalists assumes exposures of the face, forearms, and hands and a soil adherence factor of 0.07 (MDNR 1995). The unitized dermal contact rate is derived as follows:

$$\mathbf{2{,}572\ cm^2 * 0.07 * exposure\ duration\ /\ 70\ kilograms\ bodyweight}$$

The inhalation rate for recreationalists assumes an hourly inhalation rate for moderate activities of 1.0 m^3 (EPA 1997). The unitized inhalation rate is derived as follows:

$$\mathbf{1.0\ m^3 /hour * 4\ hours/day * exposure\ duration\ /\ 70\ kilograms\ bodyweight}$$

An exposure time of 4 hours per day is based on professional judgment. Additional details on the derivation of these assumptions are presented in Section 3.5.2.

3.5.2 Specific Exposure Assumptions

3.5.2.1 Fish Ingestion Rates

A key factor in assessing the risks and hazards associated with ingestion of sport-caught or subsistence-caught fish is the ingestion rates of the sport and subsistence anglers. Two key studies of fish ingestion behaviors of anglers in the Great Lakes region were conducted by Patrick West of the University of Michigan: Michigan Sport Anglers Fish Consumption Survey (1989) and Michigan Sport Anglers Fish Consumption Study (1993). In 1989, West surveyed a stratified random sample of Michigan residents with fishing licenses. Each of 18 cohorts received a questionnaire 1 week apart between January and May 1989. The survey included both a "short-term recall" component and a "usual frequency" component. The respondents were also asked to recall serving size based on comparison with a picture of a cooked 8-ounce fish portion. A total of 2,334 survey questionnaires were delivered and 1,104 were completed and returned giving a 47.3 response rate. Average fish consumption by age group, education level, place, and years of residence were reported. Because the study was conducted in the winter and spring when fishing activity may be relatively low, it may underestimate fish ingestion rates, even though respondents were asked to recall year-round consumption rates.

In 1993, a follow-up survey was conducted by West. A total of 7,000 survey questionnaires were delivered and 2,681 were completed and returned. A response rate of 46.8 was calculated by removing those respondents who could not be located or who had not resided in Michigan for at least 6 months. Estimates of fish consumption were reported by minority status and income status (low-income or non-low-income) for both sport and commercial fish. Respondents were also surveyed on education, species targeted, and cooking methods. The survey period extended for a year, covering all four seasons. The strengths of both of these surveys are sample size and reliance on short-term recall (EPA 1995c).

Minority, low-income respondents were reported to have the highest ingestion rates followed by nonminority low-income respondents. The 95th percentile ingestion rates for minority, low income (109 grams / person / day) and nonminority low-income (78 grams / person / day) respondents were used to represent subsistence and high end sport angler ingestion rates. Ingestion rates are normalized over a 365-day period by multiplying the number of fish meals by the serving size and dividing by 365 days / year. A typical serving size of 8 ounces (225 grams) is used (EPA 1996).

EPA has conducted a statistical validation of the West data showing strong correlation between 7 day recall ingestion rates and long-term recall ingestion rates (EPA 1995b). The Kalamazoo River survey may have resulted in a bias toward populations who only fished during daylight hours when the survey was conducted. The lack of interview data from Hmong anglers has been previously noted and may present a deficiency regarding subsistence fishing patterns. Responses to questions regarding catch and release practices resulted in some apparent inconsistent responses. When asked if they practice "catch and release" only, 73.5 percent of respondents answered yes, although a total of 44 percent also reported eating fish from the Kalamazoo River and / or Portage Creek. *The Kalamazoo River Angler Survey and Biological Testing Study* (MDCH 1998) was conducted to determine the utilization of the affected portions of Portage Creek and the Kalamazoo River by sport anglers or other persons who regularly eat fish from these waters. Face to face interviews were conducted with 938 individuals in Kalamazoo and Allegan Counties. Fish ingestion rates by age, education, race, gender, smoking, and drinking status were reported. About 75 percent of anglers surveyed reported they eat fish from the river no more than one meal per month (7 grams / person / day). Slightly more than 10 percent reported eating fish more often than one meal per week (32 to 65 grams / person / day). The mean ingestion rate for sport anglers was reported as 24 meals / year.

A second Kalamazoo River Angler Survey was conducted by Dr. Charles Atkin of Michigan State University (Atkin 1994). The survey was conducted via long-distance telephone interviews and included 690 respondents. Interviews were conducted in six counties: Allegan, Barry, Calhoun, Eaton, Kalamazoo, and Ottawa. Thirty-three percent of the study participants were from Kalamazoo and Allegan Counties. While the study's applicability to this HHRA is limited by the fact that less than a dozen people from Kalamazoo County and less than 50 people from Allegan County (the two counties within the KRSS) were actually asked which fish were eaten, and questions exist regarding validity of questions, answers, or data entry, several of the conclusions of the study support the use of a number of assumptions in the HHRA:

- Those who consume fish eat an average of 2.6 meals per week, slightly higher than the 2.4 meals per week used for the sport angler (high end) in the HHRA.

- Average serving size was 8.66 ounces, higher than the 8 ounce assumption used in the HHRA.

- Six percent of those surveyed overall indicated they eat bottom-feeding fish, lending additional support to include a representative bottom-feeder in the HHRA. Regarding consumption of bottom feeders, a slightly greater percentage of participants in Kalamazoo and Allegan Counties, compared to the study group overall, indicated they consume carp, catfish, and suckers.

- Thirty percent of those eating bottom feeding fish reported they sometimes or never remove or puncture the skin and 30 percent of those eating fish reported they sometimes or never trim fat from fish. These results suggest that the reduction factor used to account for trimming and cooking practices may represent more of an average than a high end value. Reduction in PCB exposure due to trimming and cooking may be higher than assumed in this assessment for relatively large number of anglers in the area.

The *Great Lakes Water Quality Initiative Technical Support Document for Human Health Criteria and Values* (EPA 1995) reports a 15 grams / person / day ingestion rate as the mean value for sport anglers in the Great Lakes Basin and as the 90th percentile for the overall population in the Basin. The value of 15 grams/person/day was derived from a review of several regional studies in Michigan, (West 1989, 1993) Wisconsin (Fiore, et al. 1989), and New York (Connelly, et al. 1990). This fish ingestion rate is used by the MDEQ Surface Water Quality Division to establish surface water quality standards. The 15 grams is divided into the grams of trophic level 3 fish consumed (3.6 grams) and the grams of trophic level 4 fish consumed (11.4 grams) as reported in the West, et al. (1993) survey. This value is also consistent with the Kalamazoo River Angler Survey (MDCH 2000), which reports a mean value for sport anglers of 24 meals/year (24 meals/year * 8 ounces/meal * 28.3 grams/ounce ÷ 1 year/365 days = 15 grams/person/day).

3.5.2.2 Species Consumed

Four species of fish were collected from the API/PC/KR during the Biota Investigation: carp, smallmouth bass, sucker, and golden redhorse. Carp and smallmouth bass were targeted as bottom dwelling fish and sport fish respectively, and representative data from analysis of fillets was available for both species. The following species were reportedly consumed by Kalamazoo River Angler Survey respondents: catfish (83.6 percent); bass (69 percent); panfish (63 percent); walleye (46 percent); bullheads (29.9 percent); carp (27 percent); and suckers (13 percent). West reported 48 percent of individuals consumed smallmouth bass and 7 percent consumed carp. In terms of species consumed, the West data are considered less reliable than the Kalamazoo River Survey because the water bodies covered included fish species not found or not prevalent in the Kalamazoo River.

Two scenarios were evaluated for both sport and subsistence anglers: 1) ingestion of 100 percent smallmouth bass; and 2) ingestion of a combination of 76 percent bass and 24 percent carp based on the percentage of trophic level 3 fish (carp) and trophic level 4 fish (smallmouth bass) reported to be consumed (West 1993). For the first scenario, exposure concentrations were based solely on smallmouth bass data collected from the site. For the second scenario, a combination of smallmouth bass and carp data were used. Total ingestion rates were apportioned across the two species accordingly. Skin-on data were used for bass and skin-off data were used for carp. Skin-on or skin-off reflects preferences found for preparation methods among anglers (West 1993).

3.5.2.3 Reduction Factors

Fish advisories typically include recommendations on trimming and cooking fish that can result in a reduction in the delivered dose of a chemical. The 2000 Michigan Fish Advisory includes the following recommendations:

- Trim fatty areas (removal of the skin, belly fat, lateral, and dorsal fat).
- Remove or puncture skin before cooking allowing the fat to drain off.
- Cook so fat drips away. Bake, broil, or grill on a rack, or poach and do not use the liquid.

- Deep-fry trimmed fillets in vegetable oil.
- Do not pan-fry in butter or animal fat, and do not make fish soups or chowder.

The advisory states that a reduction of 50 percent of the contaminants in fish can be eliminated by following these practices.

In *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (GLFATF 1993), the effects of trimming and cooking are discussed. Fish that contain high concentrations of lipids are likely to have higher concentrations of lipophilic chemicals, such as PCBs. Removal of the fatty portions of fish will reduce the overall ingestion of PCBs. Cooking typically reduces a 1/2-pound raw sample to 1/3-pound cooked weight. The Protocol reports that the contaminant concentration (on a mg/kg basis) after cooking was most often the same as before cooking, though due to the reduced size of the sample, total delivered dose would be lower.

Data reported in the Kalamazoo River Angler Survey indicate that 35 percent of anglers leave the skin on fish prior to cooking. Based on data reported by ethnicity in the 1991-1992 Michigan Sport Anglers Study, between 44 and 84 percent of minority respondents reported not trimming fat from sport fish prior to cooking. Between 23 and 40 percent reported not removing skin prior to cooking. The most popular method of cooking was reported to be pan frying by 56 percent of anglers.

Based on a review of the preparation and cooking practices reported in the Kalamazoo River Angler Survey, the Michigan Anglers Survey, and the Great Lakes Protocol, a cooking reduction factor of 50 percent was incorporated into the equations used to estimate risks and hazards for the high end sport angler and the subsistence angler. No additional reduction was assumed to result from trimming, given the practices reported in the angler surveys. In a study by Zabik and others (Zabik 1995), pesticides and total PCBs were determined in raw and cooked skin-on and skin-off chinook salmon harvested from Lakes Huron and Michigan, as well as in carp fillets harvested from Lakes Erie and Huron. The effects of baking, charbroiling, and canning salmon and pan and deep fat frying carp on contaminant loss were measured. Average losses of total PCBs for carp ranged from 30 to 35 percent (Zabik 1995). A 22 percent reduction in PCBs, expressed as micrograms per fillet in raw and pan fried skin-on carp fillets, was reported. While a 50 percent reduction factor is not in the upper range of probable values for the site, it is a reasonable estimate. Protective exposure estimates can be based on a mix of upper-range and average assumptions (EPA 1997). Using a reduction factor of 50 percent is not likely to cause substantial underestimation of possible exposures.

3.5.2.4 Fraction from Contaminated Source

The high end sport anglers were assumed to frequent different locations to fish. Some of these locations may include water bodies other than the Kalamazoo River. Fifty percent of their total fish ingestion was assumed to come from the API/PC/KR site.

Within the site, it is also possible to fish from different ABSAs, though average risks and hazards would not vary significantly depending on location within the site because detected fish concentrations are relatively consistent from ABSAs 3 through 11.

To be consistent with the MDEQ Surface Water Quality Division, the fraction of exposure from the API/PC/KR site was assumed to be 100 percent for the central tendency angler.

The subsistence angler population was assumed to be more likely to fish from one area. A low-income population may not have ready access to transportation that would allow them to travel to different areas to fish. The fraction of exposure from the API/PC/KR site was also assumed to be 100 percent for the subsistence angler population.

Nearby residents and recreationalists were assumed to receive 100 percent of their exposure to soil from the floodplain soil on days when exposure occurred.

3.5.3 Exposure Point Concentrations

Average and maximum concentrations were used to reflect a range of exposure point concentrations for the angler and nearby resident scenarios. These concentrations are presented on Tables 2-1 and 2-3.

3.5.4 Intake Equations

The intake or dose from the ingestion of fish is calculated using the equation presented on Figure 3-2 (EPA 1989). The equation for intake or dose from the ingestion, dermal, and inhalation of floodplain soil is presented in Figure 3-3 (MDEQ 1995). The values for the variables in these equations are discussed above in Section 3.5.2. Note that EPA equations do not generally present unitized contact rates for soil ingestion, dermal contact, and inhalation rates. Unitized rates, however, are simply combinations of basic parameters such as ingestion and inhalation rates, body surface area, exposure duration, and body weight. All of these parameters are included in standard EPA equations. Thus, equations in Figures 3-2 and 3-3 are exact equivalents of those presented in EPA (1997c).

Figure 3-2
Formula used for The Calculation of Intake
Fish Ingestion

$$I = \frac{C * RF * IR * FI * EF * ED}{BW * AT}$$

Where:

I	=	Intake (mg/kg-day)
C	=	Concentration in Raw Fish Filet (mg/kg) [1]
RF	=	Reduction Factor (unitless)
IR	=	Ingestion Rate (kg/day)
FI	=	Fraction Ingested (unitless)
EF	=	Exposure Frequency (days/year)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (days)

1 Intakes were estimated using both average and maximum fish tissue concentrations.

Figure 3-3
Formula used for The Calculation of Intake
Floodplain Soils - Ingestion / Dermal Contact / Inhalation

$$\mathbf{I} = \mathbf{C * FC}\left[\frac{(\mathbf{EF_i * IR_{soil} * AE_i}) + (\mathbf{EF_d * DF * AE_d}) + (\mathbf{EF_{inhal} * IR_{air} * AE_{inhal}}(\mathbf{VF + PEF}))}{\mathbf{AT * CF}}\right]$$

Where:

I	=	Intake (mg / kg-day)
C	=	Concentration in Soil (µg / kg)
FC	=	Fraction of Soil Contaminated (unitless)
IR_{soil}	=	Ingestion Rate (Soil) (mg-yr / kg-day)
DF	=	Dermal Factor (mg-yr / kg-day)
IR_{air}	=	Inhalation Rate (Air) (m^3-yr / kg-day / day)
EF_i	=	Exposure Frequency (Ingestion) (days / year)
EF_d	=	Exposure Frequency (Dermal) (days / year)
EF_{inhal}	=	Exposure Frequency (Inhalation) (days / year)
AEi	=	Absorption Efficiency (Ingestion) (unitless)
AEd	=	Absorption Efficiency (Dermal) (unitless)
AE_{inhal}	=	Absorption Efficiency (Inhalation) (unitless)
VF	=	Soil to Air Volatilization Factor (mg / m^3-air / mg / kg-soil)
PEF	=	Particulate Emission Factor (mg / m^3-air / mg / kg-soil)
AT	=	Averaging Time (days)
CF	=	Conversion Factor (µg / kg)

Section 4
Toxicity Assessment

PCBs have been associated with both cancer and noncancer health effects. Noncancer health effects include neurotoxicity, reproductive and developmental toxicity, immune system suppression, liver damage, skin irritation, and endocrine disruption (EPA 1996). A toxicity profile summarizing carcinogenic and noncarcinogenic health effects associated with PCBs is included in Appendix E. A brief overview of key studies of human health effects of PCBs is presented below.

4.1 Summary of Health Effects Associated with PCBs

ATSDR and EPA have jointly developed a technical paper, Public Health Implications of Polychlorinated Biphenyls (PCBs) Exposure. Human health studies discussed in this paper indicate that exposure to PCBs have been linked to the following health impacts:

- Effects on reproductive function in women
- Neurobehavioral and development deficits in newborns and school-age children from in utero exposure
- Liver disease, immune function impacts, and thyroid effects
- Increased cancer risks

Several studies have demonstrated a correlation between fish consumption by mothers, and developmental disorders and cognitive deficits in children. In the first of these studies, conducted by Jacobson (Jacobson, et al. 1985, 1990a, 1990b), statistically significant decreases in gestational age, birth weight, and head circumference were observed and continued to be evident 5 to 7 months after birth. Neurobehavioral deficits were observed including depressed responsiveness, impaired visual recognition, and poor short-term memory at 7 months of age, which continued to be present at 4 years of age. While recognized limitations exist in these studies, including the pooling of blood samples, which is no longer a recognized technique, more recent studies have provided supportive evidence of the relationship between PCB exposure and developmental effects.

In a study of prenatal exposure and neonatal behavioral assessment scale (NBAS) performance, cord blood PCBs, DDE, HCB, Mirex, lead, and hair mercury levels were determined for 152 women who reported never consuming Lake Ontario fish and 141 women who reported consuming at least 40 PCB-equivalent pounds of Lake Ontario fish over a lifetime. Past PCB exposure was related to impaired performance on those NBAS clusters associated with fish consumption, namely habituation and autonomic clusters. Results revealed significant linear relationships between the most heavily chlorinated PCBs and performance impairments 25 to 48 hours after birth. Higher prenatal PCB exposure was also associated with nonspecific performance impairment (Stewart, et al. 2000). Exposure to lower molecular weight PCBs (i.e., PCBs containing fewer chlorine atoms) was unrelated to NBAS performance.

Studies in Japan and Taiwan of PCB exposure from consumption of contaminated rice oil have contributed to evidence of an association between PCBs and neurobehavioral effects. The illnesses were originally referred to as Yusho disease in Japan and Yu-Cheng disease in Taiwan. In earlier studies (Bandiera, et al. 1984; Kunita, et al. 1984; Masuda and Yoshimura 1984; Ryan, et al. 1990; ATSDR 1996) co-contaminants in the rice oil, particularly chlorinated dibenzofurans (CDFs), were considered to be the primary causal agent. Recent studies, however, involving a reexamination of previous studies and newer results from a study of children born later to exposed mothers have demonstrated developmental delays associated with maternal exposure to PCBs and CDFs (Guo, et al. 1995; Chao, et al. 1997).

A study of Inuit women from Hudson Bay indicated an association between levels of PCBs and dichlorodiphenylethene (DDE) in breast milk and a statistically significant reduction in male birth length (Dewailley, et al. 1993a). No significant differences were observed between male and female newborns for birth weight, head circumference, or thyroid-stimulating hormone.

A study of 338 infants of mothers occupationally exposed to PCBs during the manufacture of capacitors indicated a decrease in gestational age (6.6 days) and a reduction in birth weight (153 grams) at birth in infants of mothers directly exposed to PCBs (Taylor, et al. 1984). A follow-up study of 405 women in this population demonstrated that serum total PCB levels in women with direct exposure to PCBs were more than four-fold higher than for women in indirect-exposure jobs. A decrease in birth weight and gestational age was found for the infants of these women (Taylor, et al. 1989).

Immune system effects on persons exposed to PCBs have been reported in several studies. A significant negative correlation between weekly consumption of fish containing PCBs from the Baltic Sea and white cell count was reported (Svensson 1994). Immune system effects were reported in Inuit infants who were believed to have received elevated levels of PCBs and dioxins from their mother's breast milk. Effects included a decline in the ratio of the CD4+ (helper) to CD8+ (cytotoxic) T-cells at ages 6 and 12 months (Dewailley, et al. 1993). Infants examined from birth to 18 months who were exposed to PCBs/dioxins in the Netherlands exhibited lower monocyte and granulocyte counts and increases in the total number of T-cells and the number of cytotoxic T-cells (Weisglas-Kuperous, et al. 1995). An increase in serum PCB levels was associated with a decrease in natural killer cells (Hagamar, et al. 1995).

Effects on the thyroid have been reported in a study of the Dutch population. Higher CDD, CDF, and PCB levels in human milk correlated significantly with lower plasma levels of maternal total triiodothyronine and total thyroxine and higher plasma levels of thyroid-stimulating hormone in infants during the second and third month after birth (ATSDR 1998).

Occupational studies show some increases in cancer mortality in workers exposed to PCBs. Significant excesses of cancer mortality were found for liver, gall bladder, and biliary tract cancer (Brown 1987), however, co-exposure to other chemicals in the workplace limits the strength of the association to PCBs. Mortality from gastrointestinal tract cancer in males and hematologic neoplasms in females was reported for capacitor workers in Italy (Bertazzi, et al. 1987). Limitations in this study include a small number of cases, short exposure period, and lack of pattern or trend when data were analyzed by duration of exposure. The results of these studies have been evaluated and are considered inconclusive by ATSDR (1996).

Evidence of an association between exposure to PCBs by capacitor workers and mortality from malignant melanoma was reported (Sinks, et al. 1992). The workers were also exposed to various solvents. More deaths were observed than expected for malignant melanoma (8 observed versus 2 expected) and cancer of the brain and central nervous system (5 observed versus 2.8 expected). Limitations include a small number of cases, insufficient monitoring data, unknown contribution of exposure to solvents, and possible bias due to the healthy worker effect. The results of this study have been evaluated and are considered inconclusive by ATSDR.

A recent study of male and female capacitor workers reported mortality from all cancers was significantly below expected for hourly male workers and comparable to expected for female workers (Kimbrough, et al. 1999). Limitations with this study include:

- Exposed and unexposed workers were included as one group diluting any potential cancer findings
- Seventy-six percent of the workers never had exposure to PCBs
- Only 4 percent of the workers had any PCB blood data and only 2 percent worked in jobs with high exposure to PCBs
- Seventy-nine percent of the workers who did die of cancer had PCB exposures less than 1 year

The ATSDR has stated it is untenable to dismiss concerns for carcinogenicity of PCBs. In 1999, the ATSDR convened an Expert Panel Review of the Toxicological Profile for PCBs. The panel concurred that the Kimbrough study of General Electric capacitor workers could not be used to dismiss the carcinogenic potential of PCBs (Bove, et al. 1999).

For reasons such as those above, EPA also concludes that the limitations of the Kimbrough study prevent conclusions to be drawn regarding the carcinogenicity of

PCBs. While all human studies have limitations and confounders, controlled animal studies, such as a long-term bioassay conducted by General Electric (Mayes 1998) provide conclusive evidence that PCBs, including the lower chlorinated forms (i.e., Aroclor 1016 and 1242) cause cancer in experimental animals. For this reason, the International Agency for Research on Cancer and EPA have concluded that the PCBs are probable human carcinogens. These conclusions are independently consistent with the National Toxicology Program's eighth Report on Carcinogens, which lists PCBs as "reasonably anticipated to be human carcinogens."

A recent study demonstrated a strong dose-response relationship between total lipid-corrected serum PCB concentrations and the risk of non-Hodgkin lymphoma (Rothman, et al. 1997). These findings are consistent with another study where residues of PCBs in adipose tissue of non-Hodgkin's lymphoma patients were higher than those of control patients (Hardell, et al. 1996). In studies of capacitor workers, significantly increased risks were reported for lymphatic/hematological malignant (LHM) diseases among female capacitor workers but non-significant increases were found for male workers (Bertazzi, et al. 1987). Two other studies found no evidence of increase in LHM among workers (Brown 1987; Sinks, et al. 1992).

Health Studies in the Great Lakes Basin

Research indicates that the primary pathway of exposure to PCBs in the Great Lakes region is from fish consumption. Recent evidence indicates an association between PCB exposures through fish consumption and reproductive and developmental effects. Newborns of mothers in the high fish consumption category exhibited a greater number of abnormal reflexes, less mature autonomic responses, and less attention to visual and auditory stimuli (Lonky, et al. 1996).

The Lake Michigan Maternal Infant Cohort study was the first epidemiologic investigation to demonstrate an association between the self-reported amounts of Lake Michigan fish eaten by pregnant women and behavioral deficits in their newborns. The 242 infants born to mothers who had eaten the greatest amount of contaminated fish during pregnancy had (1) more abnormally weak reflexes; (2) greater motor immaturity and more startle responses; and (3) less responsiveness to stimulation (ATSDR 1998). A follow-up examination of 212 children indicated that the neurodevelopmental deficits found during infancy and early childhood still persisted at age 11 years (Jacobsen and Jacobsen 1996).

In a study of nervous system dysfunction in adults exposed to PCBs and other persistent toxic substances, motor slowing and attention difficulties were directly related to the frequency of consumption of St. Lawrence Lakes fish (Mergler 1997, 1998).

In an ongoing study of Native Americans in Minnesota, Wisconsin, and Michigan preliminary results indicated elevated serum PCB levels were correlated with self-reported diabetes and liver disease (Dellinger, et al. 1997; Tarvis, et al. 1997;

Gerstenberger, et al. 1997). The average annual fish consumption rate was 23 grams per day.

In a study of the PCB congener profile in the serum of humans consuming Great Lakes fish, an established cohort of persons with robust exposure to contaminants in recreationally caught Great Lakes fish were shown to have significant quantities of serum PCBs still present 15 years after enrollment in the study. The current levels of PCBs in this group were far above those found in enrollees of more recent fish eater studies. Identification of the PCB profile in fisheaters and non-fish eaters revealed the presence of several congeners that have the potential to affect biologic or health outcomes. Investigators are currently in the process of evaluating neuropsychologic function and thyroid function in the Lake Michigan fisheaters for which PCB congener profiles were established (Humphrey, et al. 2000)

The Kalamazoo River Angler Survey (MDCH 2000b) included a second phase, which included a health survey and biological testing. In this second phase, individual self-reported medical information and fish consumption patterns were obtained and chemical analyses for PCBs, DDE, and mercury was performed on blood samples of 151 out of the original 938 survey participants. The study attempted to analyze for possible associations between chemical residue levels and self-reported health problems for fisheaters and compared chemical residue data from this study cohort to other fish eating populations previously studied.

The study reported that "medical problems reported as subjective symptoms (upset stomach, nausea, headache, or dizziness) were not measurable or quantifiable in an objective way. Statistically significant associations were not found between contaminant residues levels and self-reported medical problems. However, those anglers who considered themselves to be in good health appeared to be less likely to have blood PCB levels above median values for the aggregate group than anglers who considered themselves to be in fair/poor health."

Significantly higher levels of PCBs were found in fisheaters compared with non-fish eaters. The geometric mean for fisheaters was 2.1 ppb PCBs in blood and for non-fish eaters was 1.11 ppb PCBs in blood. Increasing residue levels for PCBs suggested a good correlation with age reflecting the persistence of these compounds in human tissues and possible higher past exposures. In contrast to previous studies of sport anglers, the Kalamazoo River Survey appears to indicate lower exposure to PCBs. Lake Michigan open water fisheaters were first evaluated in 1979-1980 and reevaluated in 1989 (Humphrey 1988; Hovinga, et al. 1992). The Lake Michigan fisheaters consumed an annual average of 32 pounds (64 meals per year) of sport-caught fish, whereas the Kalamazoo anglers consumed an annual average of 9 pounds (18 meals per year) of sport-caught fish. The Kalamazoo fisheaters more closely resembled the non-fish eaters in the Lake Michigan study.

In a comparison of Kalamazoo anglers with a survey of anglers on Wisconsin inland lakes and rivers (Fiore 1989), the following was observed: (1) Kalamazoo anglers ate on average less fish than the Wisconsin anglers but had higher PCB levels; (2) 59 of the Wisconsin anglers had no detectable PCBs while only 10 Kalamazoo River anglers were non-detectable; (3) the upper range of serum PCBs (73 ppb) reported in Kalamazoo was more than two and one-half times the upper range seen in Wisconsin (27.1 ppb).

Limitations of Phase II of the Kalamazoo River Angler Survey include: (1) selection bias in that the study group was self-selected; (2) fish consumption within the past 12 months was used as the exposure variable, rather than historic consumption; (3) response bias due to participants knowing the purpose of the study; and (4) biases associated with self-reporting health effects.

4.2 Cancer Dose Response Evaluation

A recent reevaluation of the cancer dose response relationship for PCBs introduced a new approach for evaluating cancer risks associated with PCB exposure. This approach includes a range of cancer slope factors to be used depending on the medium of exposure and the form of the PCBs (persistent PCBs, dioxin-like congeners, and tumor-promoting congeners). Other features of this approach include:

- Upper-bound and central slope estimates, with guidance on when each is appropriate

- A procedure for adjusting exposure duration to include internal exposure, reflecting persistence in the body

- Incorporation of biologically-based modeling results of tumor-promotion and cell dynamics

- Application of new principles from EPA's cancer guideline revisions (EPA 1994a, 1994b)

Three tiers of human slope factors for environmental PCBs have been developed by EPA as presented in Table 4-1. Exposure pathways to be evaluated in the HHRA fall in the high risk and persistence category with the exception of inhalation of volatile PCBs, which is in the low risk and persistence category. The upper bound slope factor (2 mg/kg-d^{-1}) is used to quantify risks for all pathways except for inhalation.

Table 4-1 Range of PCB Slope Factors, API\PC\KR Site

Level of Risk/ Resistance	Slope Factors $(mg/kg\text{-}day)^{-1}$		Criteria for Use
High Risk and Persistence	2.0	1.0	Food chain experiences Sediment or soil ingestion Dust or aerosol inhalation Dermal exposure (if absorption factor) Dioxin-like, tumor-promoting, or persistent congeners Early life exposures
Low Risk	0.4	0.3	Water ingestion Inhalation of Volatile PCBs Dermal exposure (if no absorption factor)
Lowest Risk and Persistence	0.07	0.04	Congeners with more than 4 chlorines comprise less than 0.5 percent of total PCBs

4.3 Noncancer Dose Response Evaluation

EPA has developed reference doses (RfDs) for evaluation of noncancer health effects for two Aroclors - Aroclor 1016 and 1254. Reference concentrations (RfC) have not been developed for evaluation of inhalation exposures. RfDs are therefore used to evaluate ingestion, dermal, and inhalation exposures. The health endpoint for Aroclor 1016 is reproductive effects. The health endpoint for Aroclor 1254 is immunotoxicity (EPA 1999).

Aroclor 1248 is a prevalent contaminant at the site. EPA has not developed an RfD (or other toxicity values) for Aroclor 1248 because a serious health effect, or Frank Effect (death of an offspring), was observed at the lowest dose level received by Rhesus monkeys. In general, Rhesus monkeys have shown adverse effects to PCB mixtures at doses 10-fold lower than in other species. As stated in the *Integrated Risk Information System (IRIS)* file, EPA considers these data inadequate for the derivation of an oral RfD and the chemical is classified as "Non Verifiable." A secondary source of toxicity values, the *Health Effects Assessment Summary Tables* (EPA 1997) does not provide an RfD for Aroclor 1248.

In the absence of an RfD for Aroclor 1248, the RfD for Aroclor 1254 has been used to assess risks associated with exposure to Aroclor 1248. Studies conducted on both mixtures used Rhesus monkeys. The lowest dose administered in the Aroclor 1248 study was 0.03 mg/kg-day. The lowest dose administered in the Aroclor 1254 study was 0.005 mg/kg-day. Observed health effects at the lowest dose in the Aroclor 1254 study included impairment of various immunologic functions. These effects are considered appropriate to determine "lowest observed adverse effects levels" (LOAELS). The RfDs used to evaluate noncancer health effects are presented in Table 4-2.

Table 4-2 Noncancer Toxicity Date – Oral/Dermal/Inhalation, API/PC/KR Site

Chemical of Potential Concern	Chronic/ Subchronic	Oral RfD Value	Oral RfD Units	Primary Target Organ	Combined Uncertainty/ Modifying Factors	Sources of RfD: Target Organ	Dates of RfD: Target Organ [1] (MM/DD/YY)
Aroclor 1254	Chronic	2.0E-05	mg/kg-day	Immune system - decreased antibody (IgG and IgM) response to sheep erythrocyutes	300/1	IRIS	03/08/00
Aroclor 1016	Chronic	7.0E-05	mg/kg-day	Reproductive effects - reduced birth weights	100/1	IRIS	03/08/00

(1) For IRIS values, provide the date IRIS was searched.
For Heast values, provide the date of HEAST
For NCEA values, provide the date of the article provided by NCEA.

Section 5
Risk Characterization

Risk characterization is the final step in the risk assessment process. In this step, toxicity information is combined with estimates of dose to yield quantitative estimates of cancer risk and noncancer hazard.

5.1 Overview of Noncarcinogenic Hazard Characterization

Noncarcinogenic hazard is measured in terms of a Hazard Quotient (HQ). The HQ is defined by the equation:

$$\mathbf{HQ = ADD / RfD}$$

where:

HQ	=	Hazard Quotient associated with the exposure via the specified exposure route (unitless)
ADD	=	Average Daily Dose (in mg/kg/day)
RfD	=	Reference Dose (in mg/kg/day)

or, for inhalation exposures:

$$\mathbf{HQ = [OHM]air / RfC}$$

where:

[OHM]air	=	exposure point concentration of the oil or hazardous material in air (in µg/m^3)
RfC	=	Reference Concentration or substitute toxicity value for chemical (in µg/m^3)

In evaluating the HQ, potential toxicities of individual chemicals within a mixture are assumed to be additive. Thus, HQs attributable to individual chemicals are generally summed for each receptor to obtain a cumulative hazard index (HI). Such addition is not applicable for this assessment because total PCBs are assessed as a single chemical entity for toxicological purposes.

A cumulative HI also represents the cumulative noncarcinogenic impact that the site has on a particular receptor group. The cumulative HI accounts for exposures that a receptor may receive from multiple chemicals and multiple exposure routes:

Total $HI_{route\text{-}specific} = \sum HQ_{chemical\text{-}specific}$

Cumulative $HI = \sum HI_{route\text{-}specific}$

The HQ is a unitless ratio of a receptor's exposure level (or dose) to the "acceptable" (or allowable) exposure level. A HI of 1 or less for exposure via all chemicals and routes, or a HQ of 1 or less in the event that only one contaminant and/or exposure route is/are assessed, indicates that the receptor's exposure is equal to or less than an "allowable" exposure level, and adverse health effects are considered unlikely to occur. When the cumulative HI is less than or equal to 1, a conclusion of "no significant risk of harm to human health" based on noncancer effects is appropriate. Both MDEQ and EPA have HI thresholds of 1. HQs were calculated for the various angler receptors, since only one contaminant (PCBs) and one exposure route (fish ingestion) were considered for this group of receptors. HIs were calculated for the residential and recreational receptors, however, due to the summation of HQs for the individual exposure routes of incidental ingestion, dermal contact, and inhalation of fugitive dust.

5.2 Overview of Cancer Risk Characterization

For potential carcinogens, cancer risks are obtained by the following equation:

$$\textbf{Risk} = \textbf{LADD x CSF}$$

where:

Risk	=	Excess Lifetime Cancer Risk associated with exposure to the chemical via the specified route of exposure
LADD	=	Lifetime Average Daily Dose (in mg/kg/day)
CSF	=	Cancer Slope Factor (in $[mg/kg/day]^{-1}$)

In evaluating the potential cancer risks, it is assumed that potential toxicity of chemical mixtures is additive.

MDEQ has established a cancer risk target value of 1 in 100,000 (10^{-5}). Where cumulative cancer risks exceed this threshold, MDEQ risk managers may determine that some action to reduce exposure and risk may be necessary. The MDEQ risk target falls in the middle to EPA's risk range of 1 in 1,000,000 (10^{-6}) to 1 in 10,000 (10^{-4}). EPA generally considers risks within this range "acceptable," but considerations such as size of affected population may indicate that some action to reduce risk is appropriate. Above this range, EPA risk managers will ordinarily determine that such action is necessary.

5.3 Estimation of Noncarcinogenic Hazard and Carcinogenic Risk

Estimated HQs and cancer risks for each of the seven study areas and three floodplain soil areas are presented in Figures 5-1 through 5-12 and Tables 5-1 through 5-6. The figures present only the hazard quotients/indices for the immunological endpoint, which were higher than those for the reproductive endpoint. Also, results for ABSAs

1 and 2, located upstream of API/PC/KR site sources, are included on the figures for comparative purposes. Hazard quotients/indices for both endpoints are presented in the tables. Separate estimates are presented for each of the angler scenarios, including:

- Subsistence anglers consuming 100 percent smallmouth bass (average and maximum concentrations)
- Subsistence anglers consuming 76 percent smallmouth bass and 24 percent carp (average and maximum concentrations)
- Sport anglers, high end anglers consuming 100 percent smallmouth bass (average and maximum concentrations)
- Sport anglers, high end anglers consuming 76 percent smallmouth bass and 24 percent carp (average and maximum concentrations)
- Sport anglers, CTE anglers consuming 100 percent smallmouth bass (average and maximum concentrations)
- Sport anglers, CTE anglers consuming 76 percent smallmouth bass and 24 percent carp (average and maximum concentrations)
- Residents and recreationalists living near Trowbridge, Plainwell, and Otsego Dam floodplain soils (average and maximum concentrations)

5.3.1 Subsistence Anglers

5.3.1.1 Cancer Risks

As presented on Tables 5-1 and 5-2 and Figures 5-1 through 5-4, cancer risks to subsistence anglers who ingested either 100 percent smallmouth bass or 76 percent smallmouth bass and 24 percent carp exceeded MDEQ and EPA cancer risk thresholds for both average exposure point concentrations (EPCs) and maximum EPC scenarios for all ABSAs in the API/PC/KR site. Cancer risks were in the range at or above 1 in 10,000 for study areas ABSA 3, 4, 5 (combined), ABSAs 6 and 11 for average concentrations, and ABSA 11 for maximum concentrations. Cancer risks were in the range at or above 1 in 1,000 for both average EPCs and maximum EPC scenarios for all other ABSAs. The highest cancer risks for the single species scenario was in ABSA 9, where cancer risks using maximum concentrations were estimated as 4 in 1,000. The highest cancer risks for the mixed species scenario were in ABSA 3, 4, 5 (combined), where risks using maximum concentrations were 5 in 1,000.

Range of Cancer Risk Estimates by ABSA and by Exposure Scenario Based on Average Concentrations of PCBs in Smallmouth Bass (100% of Consumption)

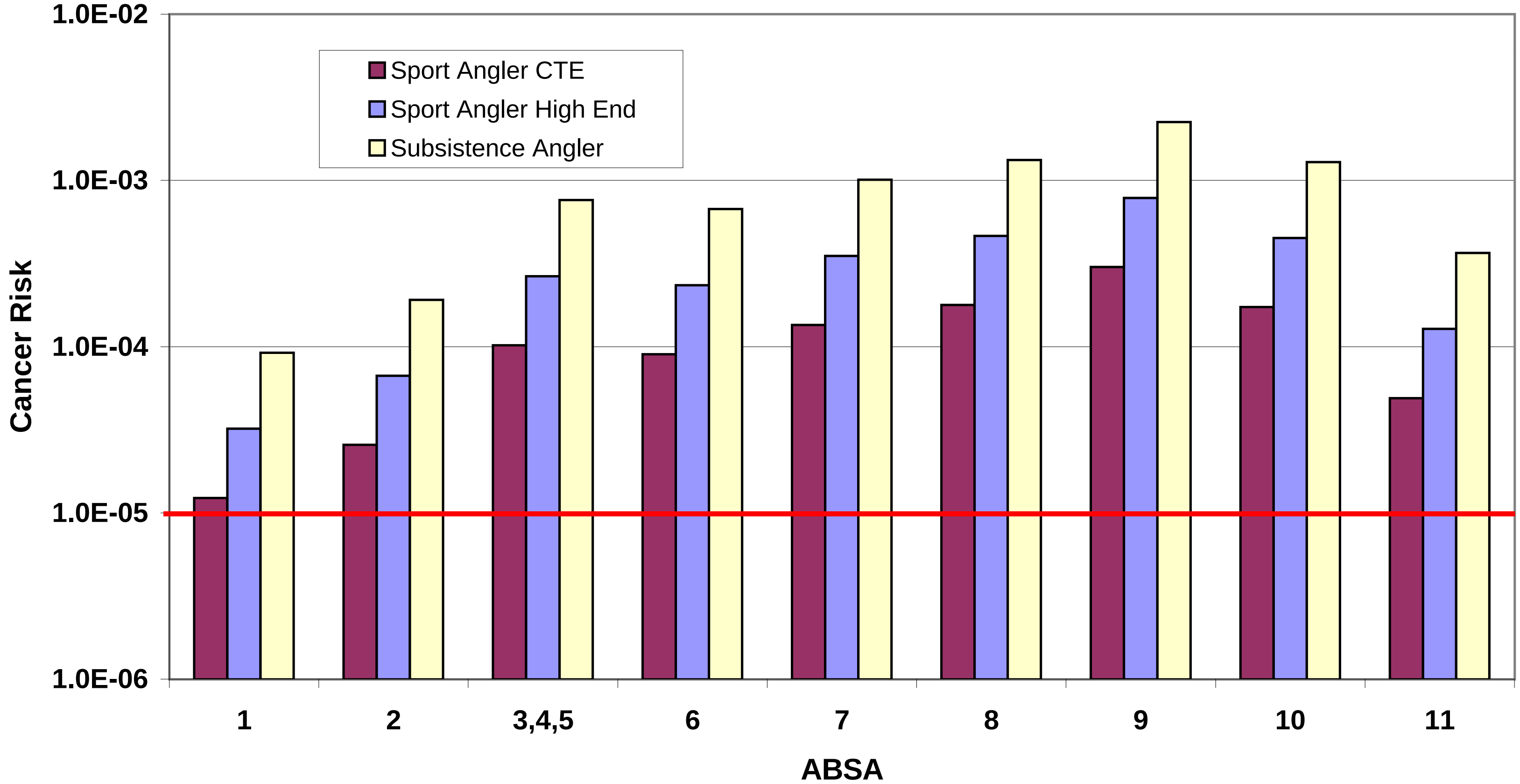


FIGURE 5-1

API/PC/KR SITE

Range of Cancer Risk Estimates by ABSA and by Exposure Scenario Based on Maximum Concentrations of PCBs in Smallmouth Bass (100% of Consumption)

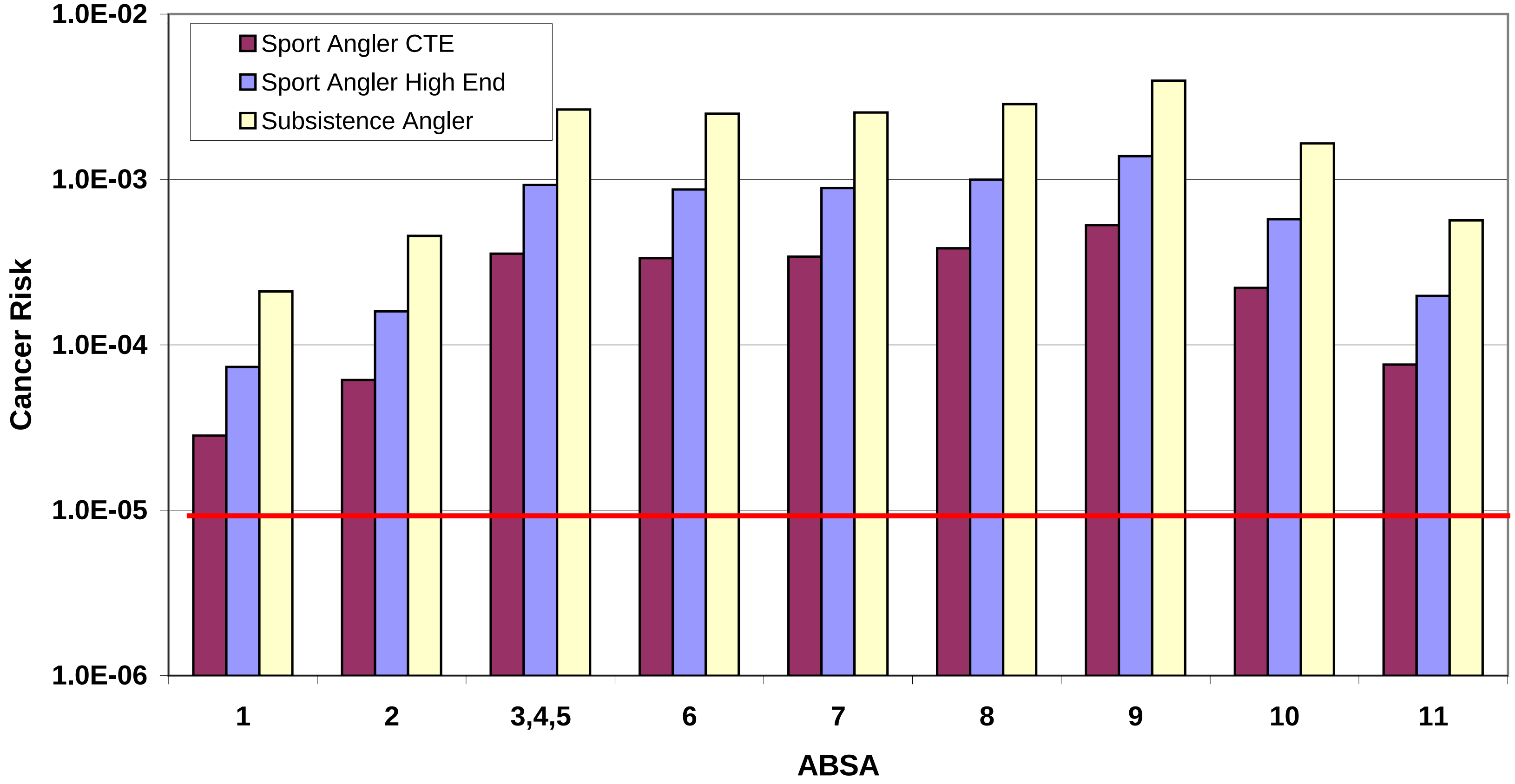


FIGURE 5-2

API/PC/KR SITE

Range of Cancer Risk Estimates by ABSA and by Exposure Scenario Based on Average Concentrations of PCBs in Smallmouth Bass (76% of Consumption) and Carp (24% of Consumption)

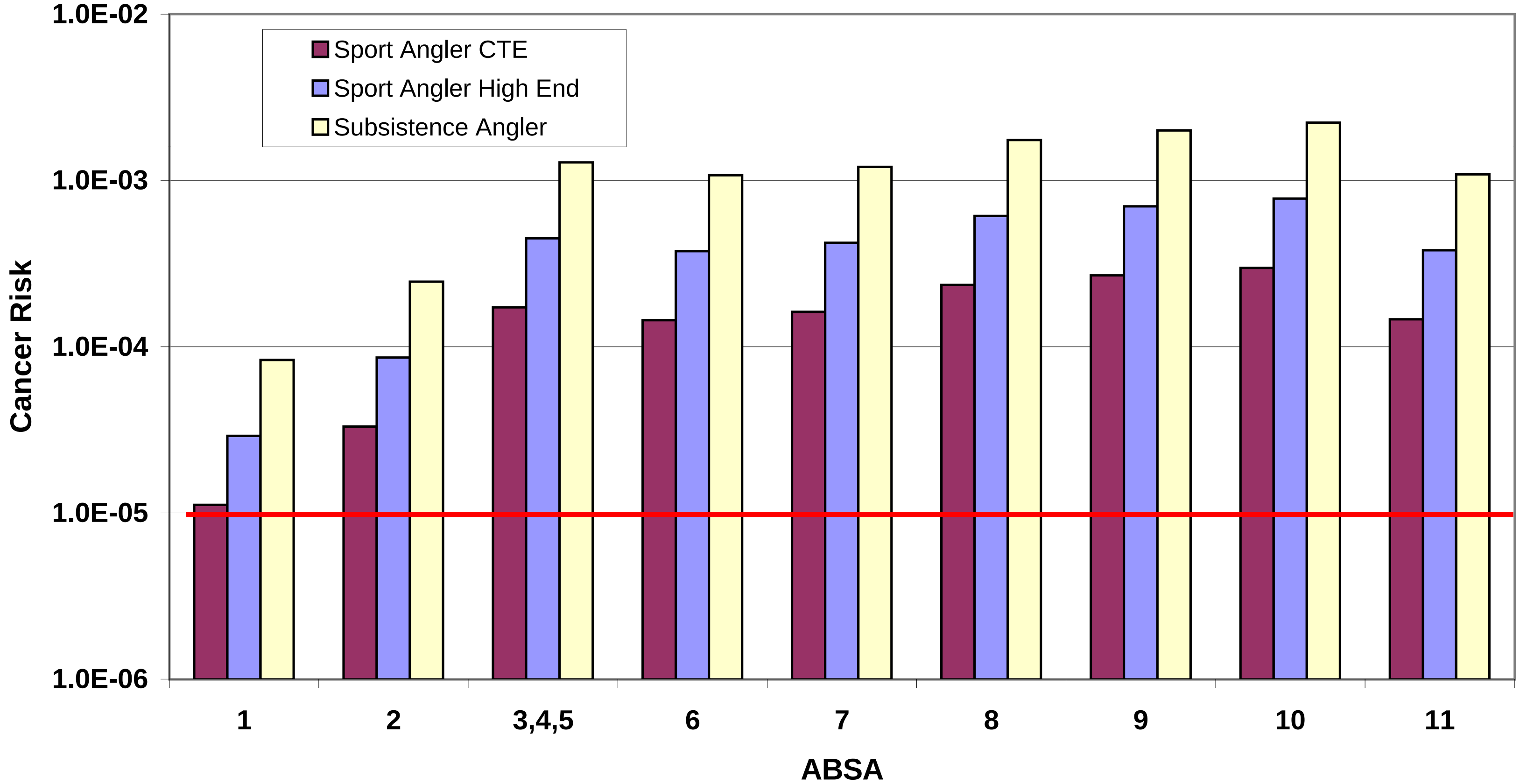


FIGURE 5-3

API/PC/KR SITE

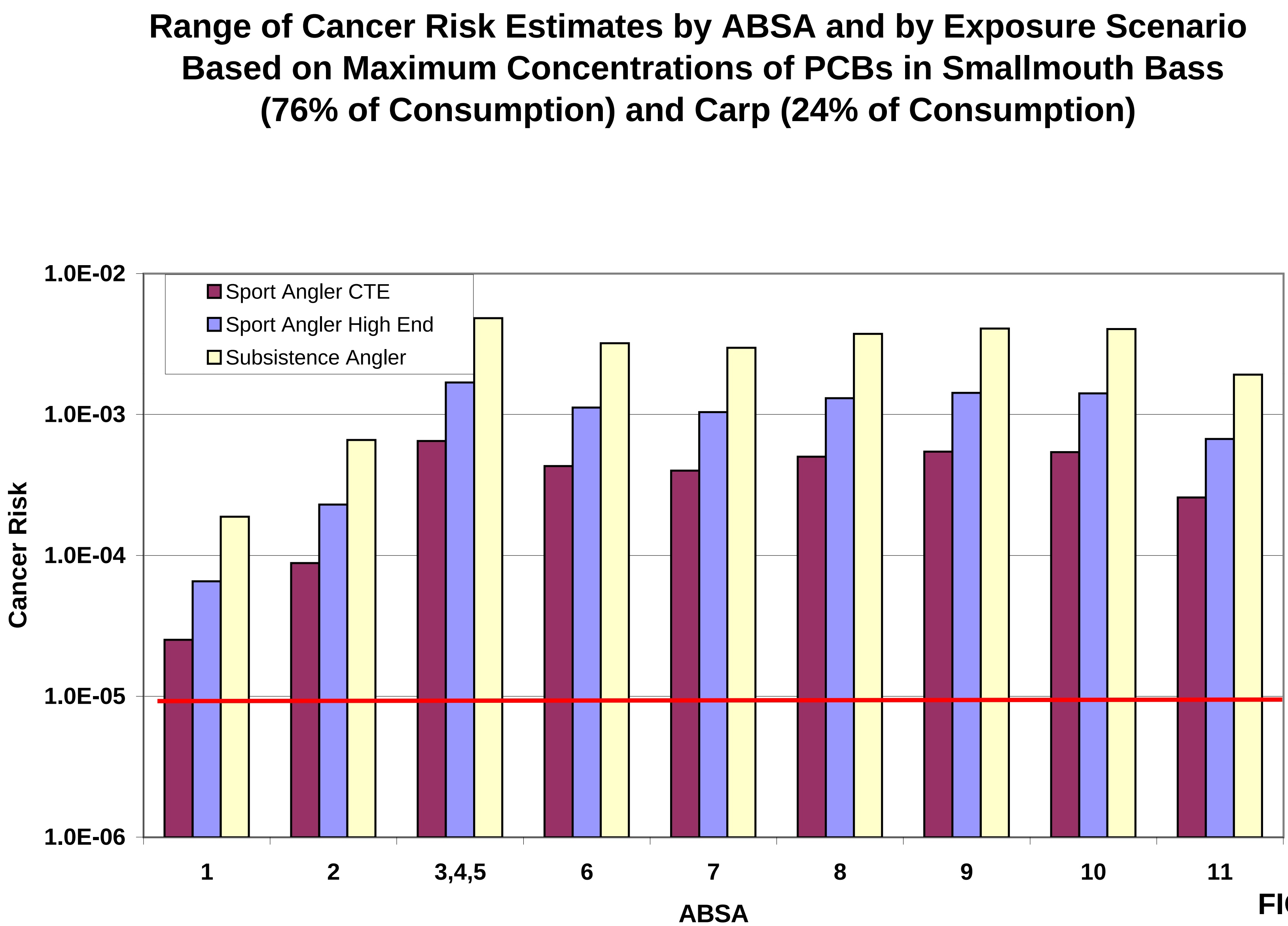


FIGURE 5-4

API/PC/KR SITE

Range of Hazard Estimates by ABSA and by Exposure Scenario Immunological Endpoint Based on Average Concentrations of PCBs in Smallmouth Bass (100% of Consumption)

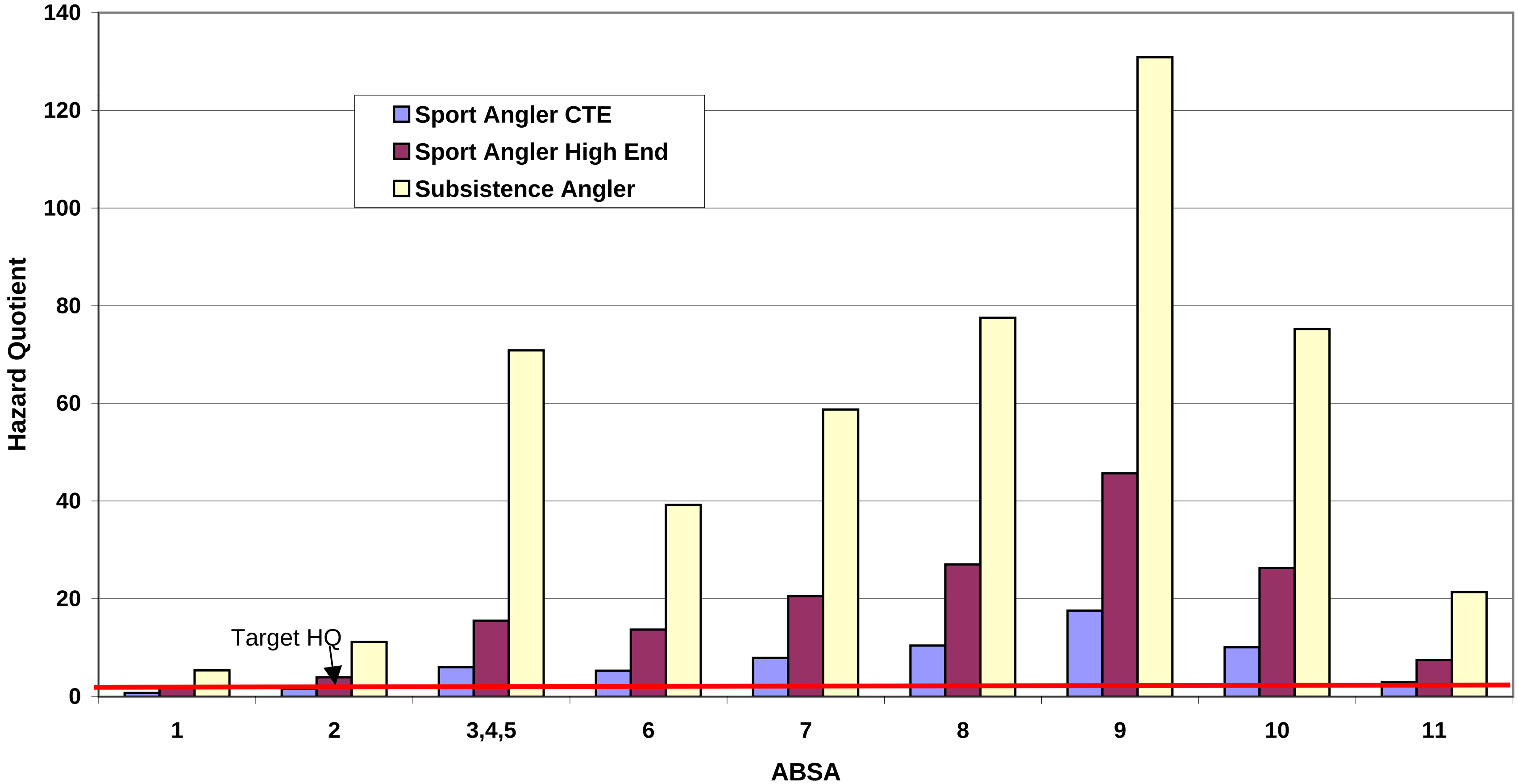


FIGURE 5-5

API/PC/KR SITE

Range of Hazard Estimates by ABSA and by Exposure Scenario Immunological Endpoint Based on Maximum Concentrations of PCBs in Smallmouth Bass (100% of Consumption)

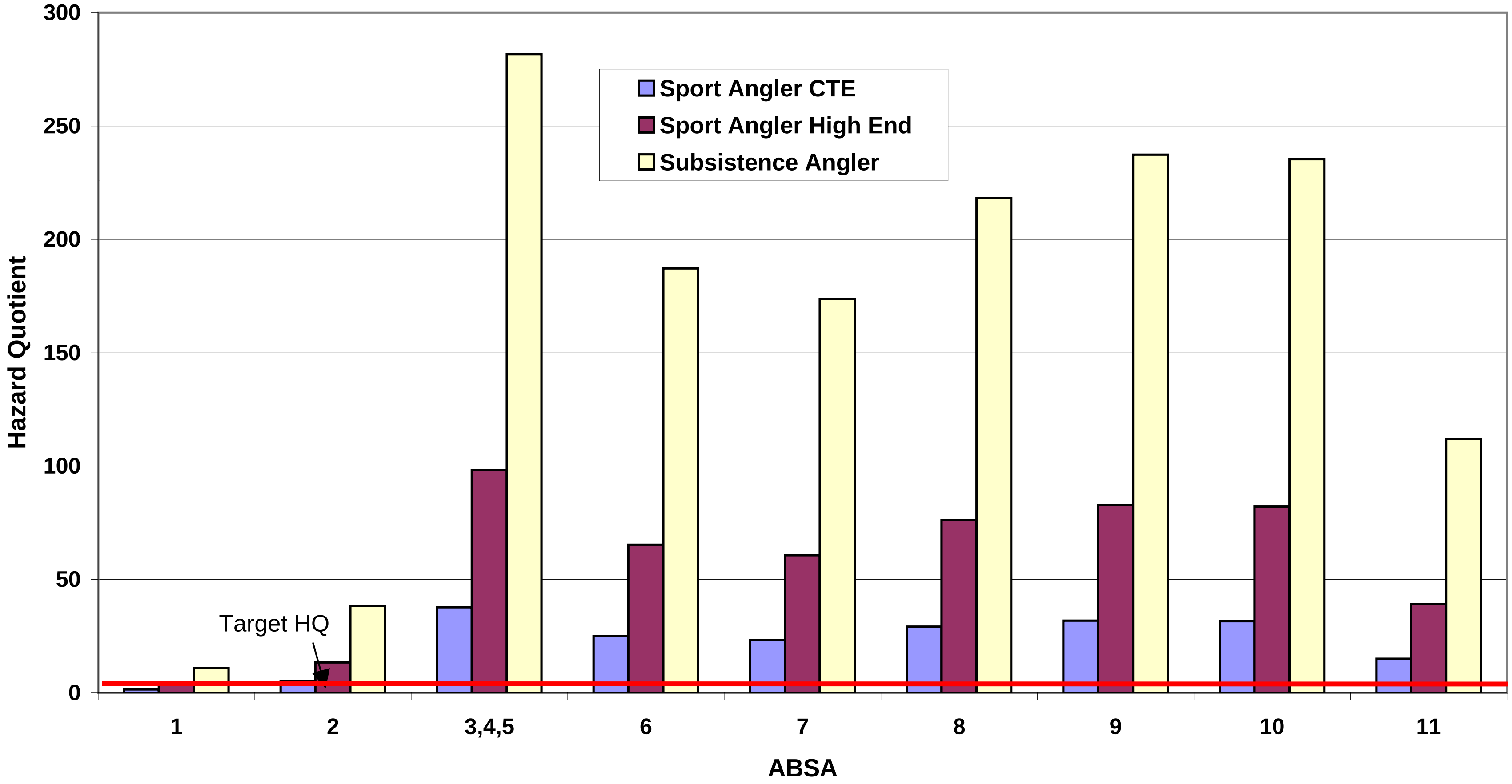


FIGURE 5-6

API/PC/KR SITE

Range of Hazard Estimates by ABSA and by Exposure Scenario Immunological Endpoint Based on Average Concentrations of PCBs in Smallmouth Bass (76% of Consumption) and Carp (24% of Consumption)

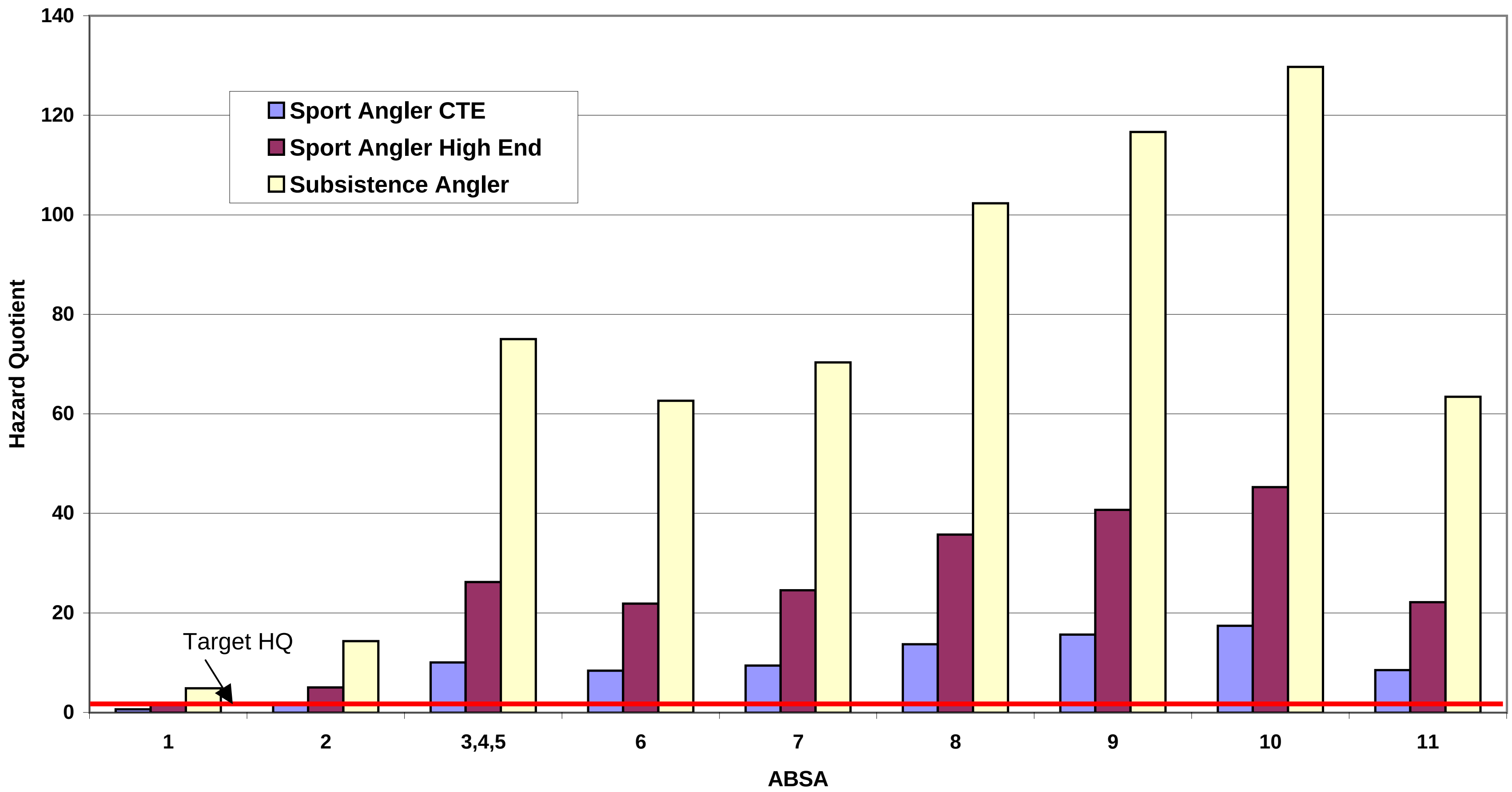


FIGURE 5-7

API/PC/KR SITE

Range of Hazard Estimates by ABSA and by Exposure Scenario Immunological Endpoint Based on Maximum Concentrations of PCBs in Smallmouth Bass (76% of Consumption) and Carp (24% of Consumption)

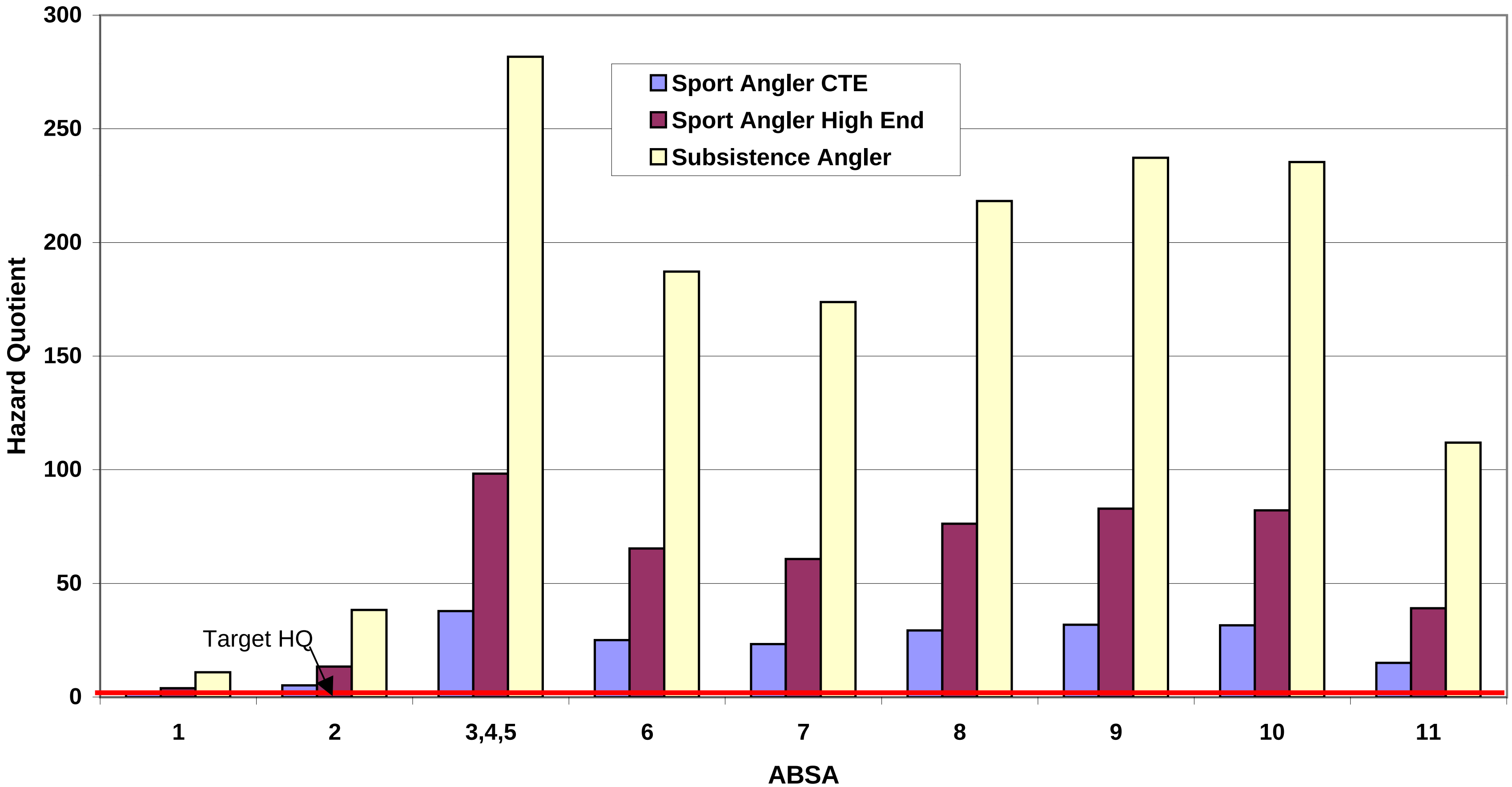


FIGURE 5-8

API/PC/KR SITE

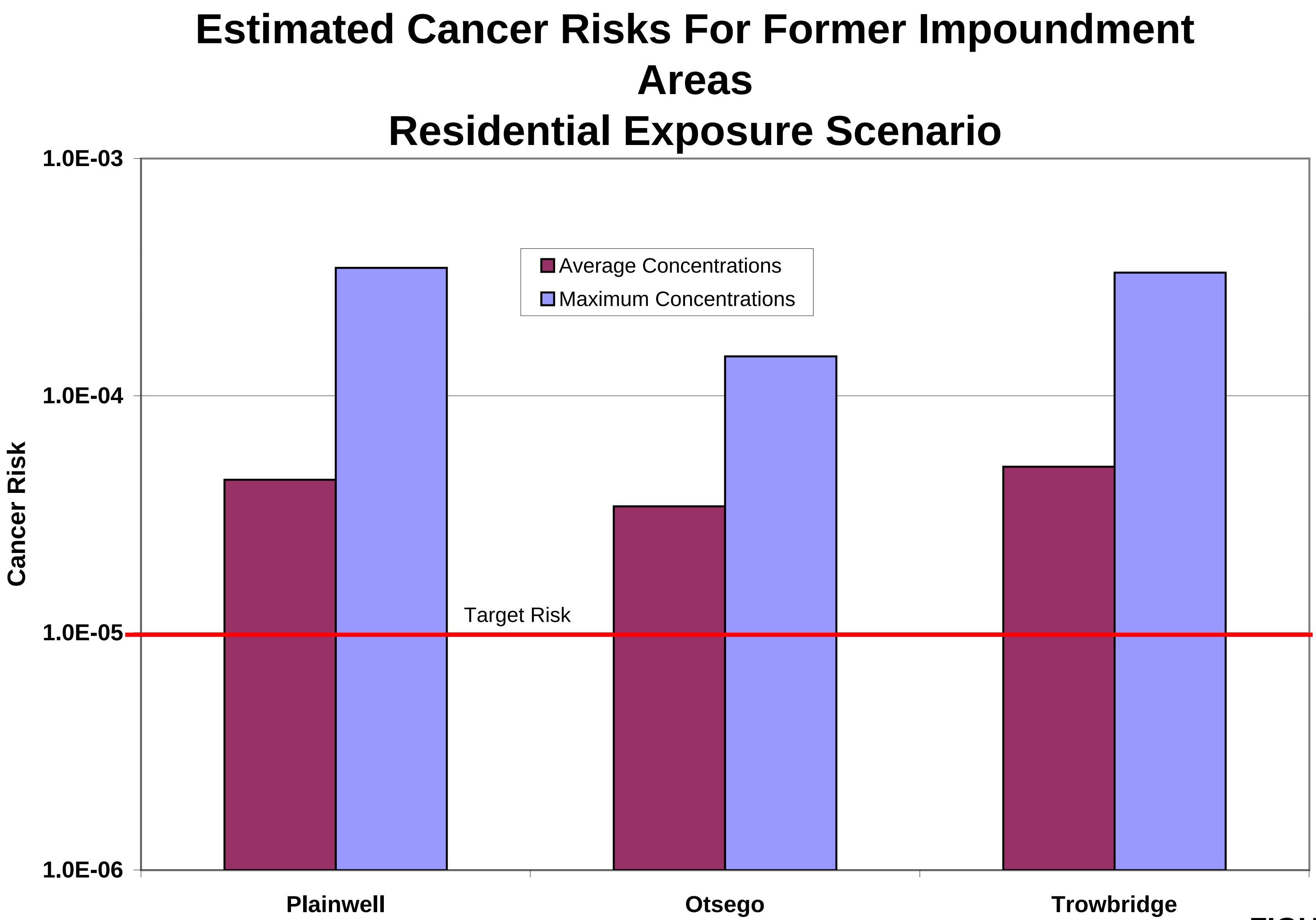


FIGURE 5-9

AP/PC/KR SITE

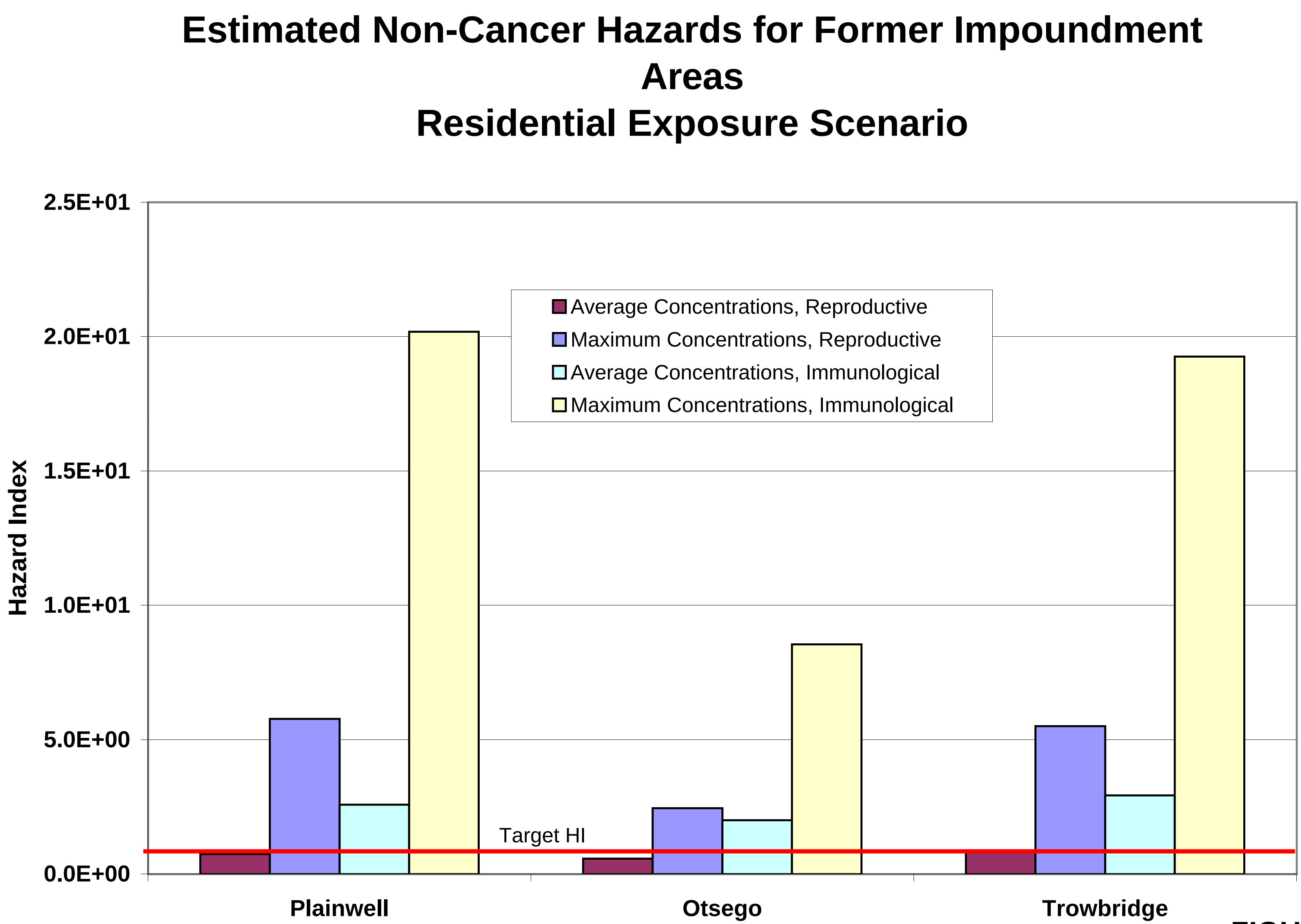


FIGURE 5-10

AP/PC/KR SITE

Estimated Cancer Risks for Former Impoundment Areas
Recreational Exposure Scenario

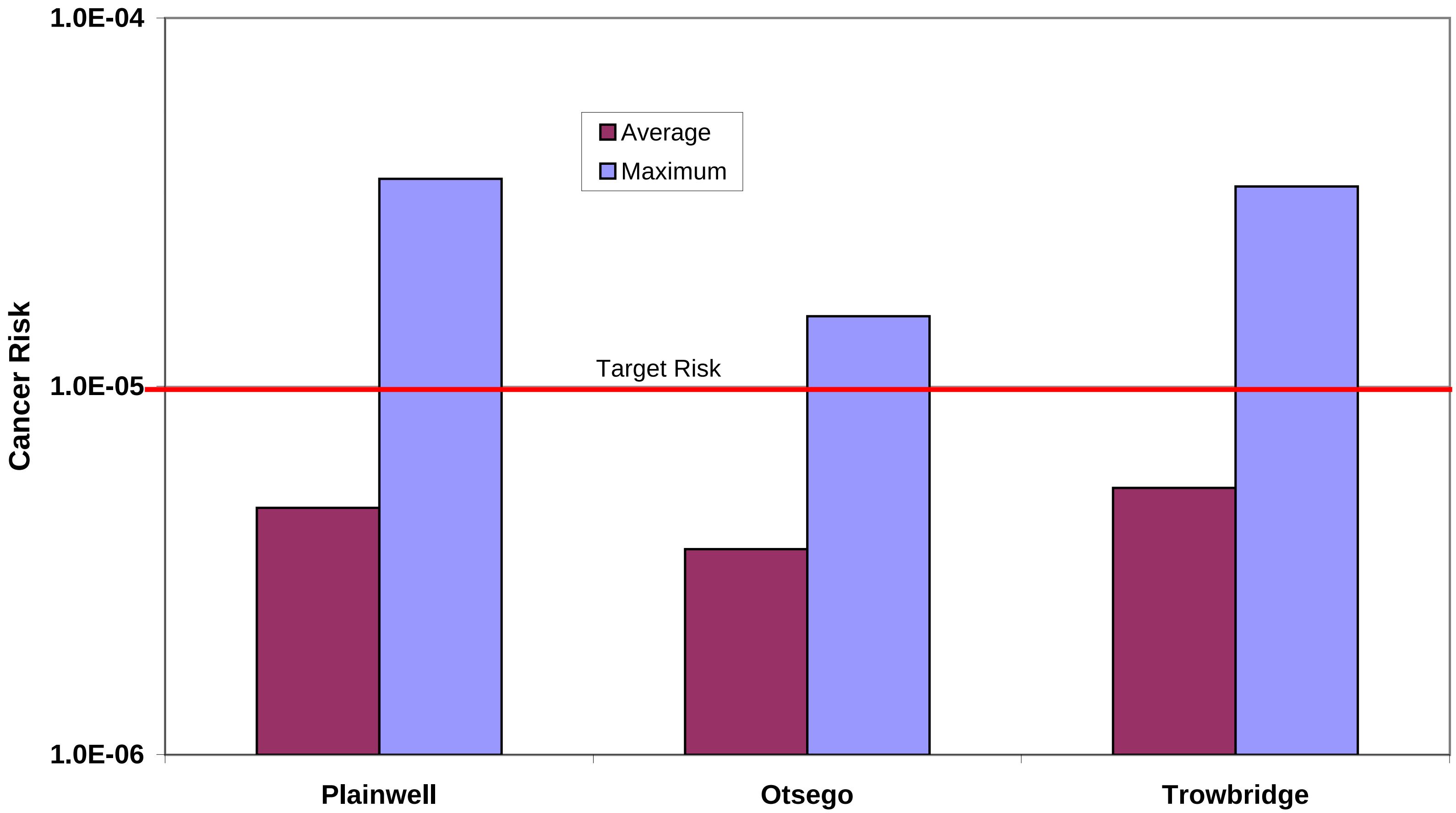


FIGURE 5-11

AP/PC/KR SITE

Estimated Non-Cancer Hazards for Former Impoundment Areas
Recreational Exposure Scenario

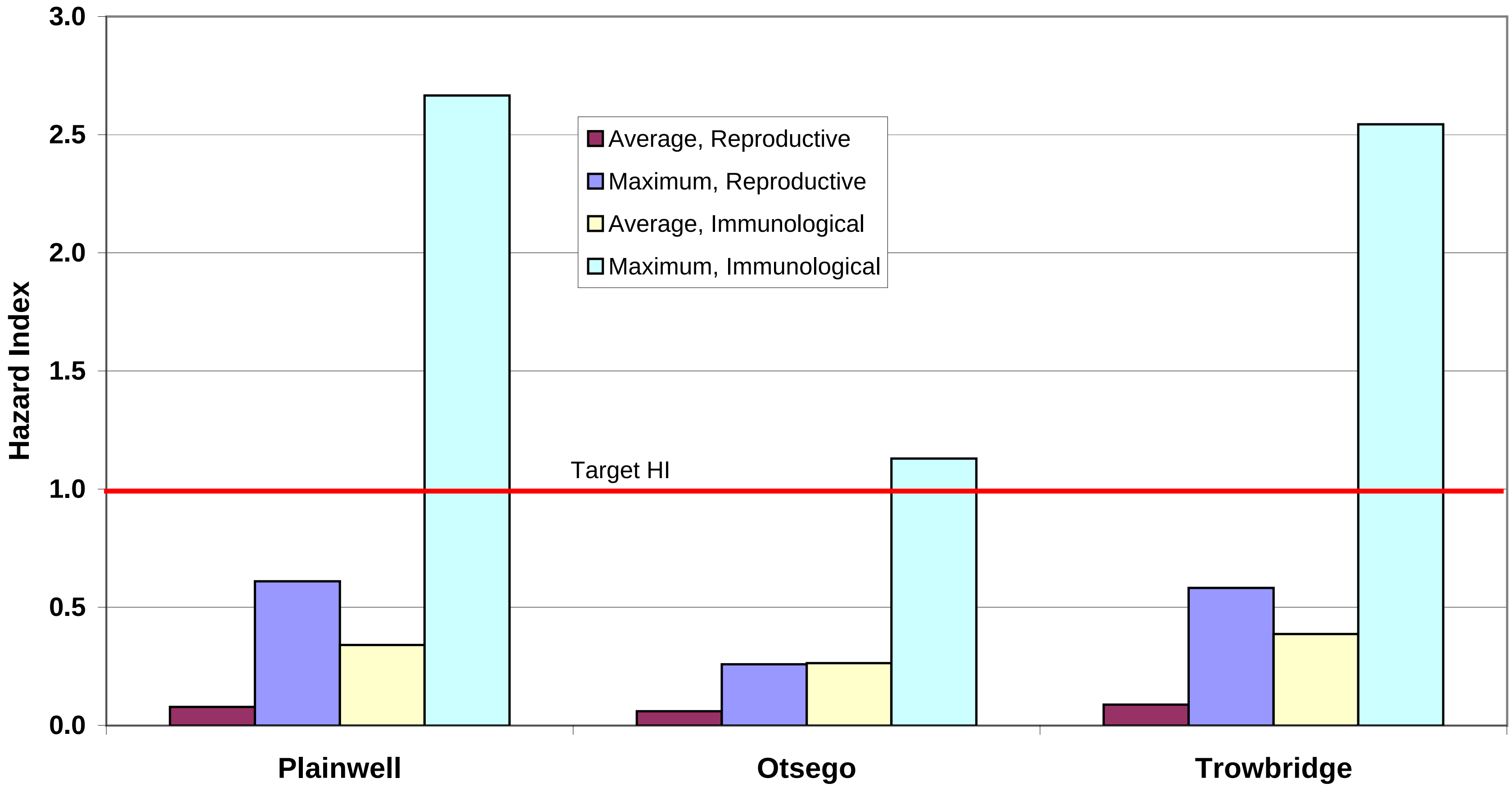


FIGURE 5-12

AP/PC/KR SITE

Table 5-1 Summary of Risks and Hazards for Subsistence and Sport Anglers Average Concentrations API/PC/KR Site

				Carcinogenic Risk from Ingestion of Fish					
				Subsistence		Sport - Central Tendency		Sport - High End	
Source Medium	Exposure Medium	Exposure Point	Chemical	100% SMB	76% SMB/ 24% CARP	100% SMB	76% SMB/ 24% CARP	100% SMB	76% SMB/ 24% CARP
Fish	Fish	ABSA 3,4,5 (Combined)	Total PCBs	7.6E-04	1.3E-03	1.0E-04	1.7E-04	2.7E-04	4.5E-04
		ABSA 6	Total PCBs	6.7E-04	1.1E-03	9.0E-05	1.4E-04	2.3E-04	3.7E-04
		ABSA 7	Total PCBs	1.0E-03	1.2E-03	1.4E-04	1.6E-04	3.5E-04	4.2E-04
		ABSA 8	Total PCBs	1.3E-03	1.8E-03	1.8E-04	2.4E-04	4.6E-04	6.1E-04
		ABSA 9	Total PCBs	2.2E-03	2.0E-03	3.0E-04	2.7E-04	7.8E-04	7.0E-04
		ABSA 10	Total PCBs	1.3E-03	2.2E-03	1.7E-04	3.0E-04	4.5E-04	7.8E-04
		ABSA 11	Total PCBs	3.7E-04	1.1E-03	4.9E-05	1.5E-04	1.3E-04	3.8E-04

Notes: Target cancer risk range: 1E-06 to 1E-04 (EPA); 1E-05 (MDEQ)

				Noncarcinogenic Hazard Quotient from Ingestion of Fish					
				Subsistence		Sport - Central Tendency		Sport - High End	
Source Medium	Exposure Medium	Exposure Point	Chemical	100% SMB	75% SMB/ 25% CARP	100% SMB	75% SMB/ 25% CARP	100% SMB	75% SMB/ 25% CARP
Fish	Fish	ABSA 3,4,5 (Combined)	Total PCBs	13 (R) 71 (I)	21 (R) 75 (I)	1.7 (R) 5.9 (I)	2.9 (R) 10 (I)	4.4 (R) 15 (I)	7.5 (R) 26 (I)
		ABSA 6	Total PCBs	11 (R) 39 (I)	18 (R) 63 (I)	1.5 (R) 5.3 (I)	2.4 (R) 8.4 (I)	3.9 (R) 14 (I)	6.2 (R) 22 (I)
		ABSA 7	Total PCBs	17 (R) 59 (I)	20 (R) 70 (I)	2.3 (R) 7.9 (I)	2.7 (R) 9.4 (I)	5.9 (R) 21 (I)	7.0 (R) 25 (I)
		ABSA 8	Total PCBs	22 (R) 77 (I)	29 (R) 100 (I)	3.0 (R) 10 (I)	3.9 (R) 14 (I)	7.7 (R) 27 (I)	10 (R) 36 (I)
		ABSA 9	Total PCBs	37 (R) 130 (I)	33 (R) 120 (I)	5.0 (R) 18 (I)	4.5 (R) 16 (I)	13 (R) 46 (I)	12 (R) 41 (I)
		ABSA 10	Total PCBs	21 (R) 75 (I)	37 (R) 130 (I)	2.9 (R) 10 (I)	5.0 (R) 17 (I)	7.5 (R) 26 (I)	13 (R) 45 (I)
		ABSA 11	Total PCBs	6.1 (R) 21 (I)	18 (R) 63 (I)	.82 (R) 2.9 (I)	2.4 (R) 8.5 (I)	2.1 (R) 7.5 (I)	6.3 (R) 22 (I)

Notes: Target hazard quotient: 1.0 (EPA and MDEQ)
(R): Reproductive endpoint
(I): Immunological endpoint

Table 5-2 Summary of Risks and Hazards for Subsistence and Sport Anglers Maximum Concentrations API/PC/KR Site

				Carcinogenic Risk from Ingestion of Fish					
				Subsistence		**Sport - Central Tendency**		**Sport - High End**	
Source Medium	**Exposure Medium**	**Exposure Point**	**Chemical**	**100% SMB**	**76% SMB/ 24% CAR**	**100% SMB**	**76% SMB/ 24% CAR**	**100% SMB**	**76% SMB/ 24% CAR**
Fish	Fish	ABSA 3,4,5 (Combined)	Total PCBs	2.7E-03	4.8E-03	3.6E-04	6.5E-04	9.3E-04	1.7E-03
		ABSA 6	Total PCBs	2.5E-03	3.2E-03	3.3E-04	4.3E-04	8.7E-04	1.1E-03
		ABSA 7	Total PCBs	2.5E-03	3.0E-03	3.4E-04	4.0E-04	8.9E-04	1.0E-03
		ABSA 8	Total PCBs	2.9E-03	3.7E-03	3.8E-04	5.0E-04	1.0E-03	1.3E-03
		ABSA 9	Total PCBs	4.0E-03	4.1E-03	5.3E-04	5.5E-04	1.4E-03	1.4E-03
		ABSA 10	Total PCBs	1.6E-03	4.0E-03	2.2E-04	5.4E-04	5.8E-04	1.4E-03
		ABSA 11	Total PCBs	5.7E-04	1.9E-03	7.6E-05	2.6E-04	2.0E-04	6.7E-03

Notes: Target cancer risk range: 1E-06 to 1E-04 (EPA); 1E-05 (MDEQ)

				Noncarcinogenic Hazard Quotient from Ingestion of Fish					
				Subsistence		**Sport - Central Tendency**		**Sport - High End**	
Source Medium	**Exposure Medium**	**Exposure Point**	**Chemical**	**100% SMB**	**75% SMB/ 25% CARP**	**100% SMB**	**75% SMB/ 25% CAR**	**100% SMB**	**76% SMB/ 24% CAR**
Fish	Fish	ABSA 3,4,5 (Combined)	Total PCBs	44 (R) 150 (I)	80 (R) 280 (I)	5.9 (R) 21 (I)	11 (R) 38 (I)	15 (R) 54 (I)	28 (R) 98 (I)
		ABSA 6	Total PCBs	42 (R) 150 (I)	53 (R) 190 (I)	5.6 (R) 20 (I)	7.2 (R) 25 (I)	15 (R) 51 (I)	19 (R) 65 (I)
		ABSA 7	Total PCBs	42 (R) 150 (I)	50 (R) 170 (I)	5.7 (R) 20 (I)	6.7 (R) 23 (I)	15 (R) 52 (I)	17 (R) 61 (I)
		ABSA 8	Total PCBs	48 (R) 170 (I)	62 (R) 220 (I)	6.4 (R) 22 (I)	8.4 (R) 29 (I)	17 (R) 58 (I)	22 (R) 76 (I)
		ABSA 9	Total PCBs	66 (R) 230 (I)	68 (R) 240 (I)	8.8 (R) 31 (I)	9.1 (R) 32 (I)	23 (R) 81 (I)	24 (R) 83 (I)
		ABSA 10	Total PCBs	27 (R) 96 (I)	67 (R) 240 (I)	3.7 (R) 13 (I)	9.0 (R) 32 (I)	9.6 (R) 34 (I)	23 (R) 82 (I)
		ABSA 11	Total PCBs	9.4 (R) 33 (I)	32 (R) 110 (I)	1.3 (R) 4.4 (I)	4.3 (R) 15 (I)	3.3 (R) 12 (I)	11 (R) 39 (I)

Notes: Acceptable hazard quotient: 1.0 (EPA and MDEQ)
(R): Reproductive endpoint
(I): Immunological endpoint

Table 5-3 Summary of Risks and Hazards for Residents Living Near Exposed Floodplain Soils Average Concentrations API/K/KR Site

Source Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk Exposure Routes Total	Chemical	Noncarcinogenic Hazard Index Exposure Routes Total
Floodplain Soils	Floodplain Soils	Trowbridge	Total PCBs	5.0E-05	Total PCBs	0.84 (R) 2.9 (I)
Floodplain Soils	Floodplain Soils	Otsego	Total PCBs	3.4E-05	Total PCBs	0.57 (R) 2.0 (I)
Floodplain Soils	Floodplain Soils	Plainwell	Total PCBs	4.4E-05	Total PCBs	0.74 (R) 2.6 (I)

Notes: Target cancer risk range: 1E-06 to 1E-04 (EPA); 1E-05 (MDEQ)
Acceptable hazard index: 1.0 (EPA and MDEQ)
(R): Reproductive endpoint
(I): Immunological endpoint

Table 5-4 Summary of Risks and Hazards for Residents Living Near Exposed Floodplain Soils Maximum Concentrations API/PC/KR Site

Source Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk Exposure Routes Total	Chemical	Noncarcinogenic Hazard Index Exposure Routes Total
Floodplain Soils	Floodplain Soils	Trowbridge	Total PCBs	3.3E-04	Total PCBs	5.5 (R) 19 (I)
Floodplain Soils	Floodplain Soils	Otsego	Total PCBs	1.5E-04	Total PCBs	2.4 (R) 8.5 (I)
Floodplain Soils	Floodplain Soils	Plainwell	Total PCBs	3.5E-04	Total PCBs	5.8 (R) 20 (I)

Notes: Target cancer risk range: 1E-06 to 1E-04 (EPA); 1E-05 (MDEQ)
Acceptable hazard index: 1.0 (EPA and MDEQ)
(R): Reproductive endpoint
(I): Immunological endpoint

Table 5-5 Summary of Risks and Hazards for Recreational Visitors to Exposed Floodplain Soils Average Concentrations API/K/KR Site

Source Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk Exposure Routes Total	Chemical	Noncarcinogenic Hazard Index Exposure Routes Total
Floodplain Soils	Floodplain Soils	Trowbridge	Total PCBs	5.3E-06	Total PCBs	0.008 (R) 0.39 (I)
Floodplain Soils	Floodplain Soils	Otsego	Total PCBs	3.6E-06	Total PCBs	0.006 (R) 0.26 (I)
Floodplain Soils	Floodplain Soils	Plainwell	Total PCBs	4.7E-06	Total PCBs	0.008 (R) 0.34 (I)

Notes: Target cancer risk range: 1E-06 to 1E-04 (EPA); 1E-05 (MDEQ)
Acceptable hazard index: 1.0 (EPA and MDEQ)

Table 5-6 Summary Of Risks And Hazards For Recreational Visitors To Exposed Floodplain Soils Maximum Concentrations API/PC/KR Site

Source Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk Exposure Routes Total	Chemical	Noncarcinogenic Hazard Index Exposure Routes Total
Floodplain Soils	Floodplain Soils	Trowbridge	Total PCBs	3.5E-05	Total PCBs	0.58 (R) 2.5 (I)
Floodplain Soils	Floodplain Soils	Otsego	Total PCBs	1.5E-05	Total PCBs	0.26 (R) 1.1 (I)
Floodplain Soils	Floodplain Soils	Plainwell	Total PCBs	3.7E-05	Total PCBs	0.61 (R) 2.7 (I)

Notes: Target cancer risk range: 1E-06 to 1E-04 (EPA); 1E-05 (MDEQ)
Acceptable hazard index: 1.0 (EPA and MDEQ)

Note that risks were relatively high for ABSAs 1 and 2, although still much lower than those for site ABSAs (3 through 11). These areas, upstream of the source areas associated with the API/PC/KR site, may be influenced by non-site related sources of PCBs. Fish from ABSA 2, which includes Morrow Lake behind Morrow Pond Dam, have higher average and maximum PCB concentrations than fish taken from areas further upstream.

5.3.1.2 Noncancer Hazard

Noncancer hazards to subsistence anglers were estimated for both reproductive and immunological effects. As presented in Tables 5-1 and 5-2 and Figures 5-5 through 5-8, HQs for both endpoints for all scenarios using both average and maximum EPCs exceed the regulatory HQ threshold of 1 for all ABSAs in the API/PC/KR site.

The HQ for the average exposure point scenario ranged between 6 and 37 for the reproductive endpoint and 21 and 130 for the immunological endpoint for single species ingestion. For mixed species ingestion, the HQ ranged from 18 to 37 for the reproductive endpoint and from 63 to 130 for the immunological endpoint.

The HQ for the maximum exposure point scenario ranged between 9 and 66 for the reproductive endpoint and 33 and 230 for the immunological endpoint for single species. For mixed species, the HQ ranged from 32 to 80 for the reproductive endpoint and from 110 to 280 for the immunological endpoint.

As discussed in Section 5.3.1.1, HQs for upstream ABSAs 1 and 2 are relatively high, suggesting some non-site related sources of PCBs above. HQs for ABSA 2 exceed the threshold of 1, although these HQs remain many times lower than those calculated for exposure in ABSAs 3 through 11.

5.3.2 Sport Anglers - High End

5.3.2.1 Cancer Risks

As presented on Tables 5-1 and 5-2 and Figures 5-1 through 5-4, cancer risks to high end sport anglers exceeded both EPA and MDEQ cancer risk thresholds for all ABSAs in the API/PC/KR site for both the average EPC and maximum EPC scenarios for both single and multiple species. Cancer risks for average EPCs ingesting single species were all at or above 1 in 10, 000. Cancer risks to high end sport anglers using maximum EPCs ingesting single species were all at or above 1 in 10,000 except for ABSAs 8 and 9, where risks exceeded 1 in 1,000. Cancer risks to sport anglers ingesting multiple species were in the 1 in 10,000 or higher range using average EPCs and 1 in 1,000 or higher using maximum EPCs. The highest cancer risk for high end anglers ingesting single species were estimated for ABSA 9 using average and maximum EPCs with estimated risks of 8 in 10,000 and 1 in 1,000, respectively. For multiple species ingestion, the highest cancer risks were estimated for ABSA 10 using average EPCs, and in ABSA 11 using maximum EPCs with estimated risks of 8 in 10,000 and 7 in 1,000, respectively.

As discussed in Section 5.3.1.1, risks were relatively high for ABSAs 1 and 2, although still much lower than those for site ABSAs (3 through 11). These areas, upstream of the source areas associated with the API/PC/KR site, may be influenced by non-site related sources of PCBs. Fish from ABSA 2, which includes Morrow Lake behind Morrow Pond Dam, have higher average and maximum PCB concentrations than fish taken from areas further upstream.

5.3.2.2 Noncancer Hazard

As presented in Tables 5-1 and 5-2 and Figures 5-5 through 5-8, scenarios exceeded a HQ of 1 for both the immunological and reproductive endpoints. The HQ for the average EPC scenario ranged from 2 to 13 for the reproductive endpoint and 7.5 to 46 for the immunological endpoint for single species ingestion. For mixed species, the HQ ranged between 6 and 13 for the reproductive endpoint, and 22 and 45 for the immunological endpoint for multiple species.

The HQ for the maximum EPC scenario ranged from 3 to 23 for the reproductive endpoint and from 12 to 81 for the reproductive endpoint. For mixed species, the HQ for the reproductive endpoint ranged from 11 to 28, and for the immunological endpoint ranged from 39 to 98.

As discussed in Section 5.3.1.1, HQs for upstream ABSAs 1 and 2 are relatively high, suggesting some non-site related sources of PCBs above. HQs for ABSA 2 exceed the threshold of 1, although these HQs remain many times lower than those calculated for exposure in ABSAs 3 through 11.

5.3.3 Sport Anglers - Central Tendency

5.3.3.1 Cancer Risks

As presented on Tables 5-1 and 5-2 and Figures 5-1 through 5-4, cancer risks to central tendency sport anglers exceeded both EPA and MDEQ cancer risk thresholds for both the average and maximum EPC scenarios for both single and multiple species for all ABSAs in the API/PC/KR site with two exceptions. For the single species scenario using average EPCs, cancer risks were all at or above 1 in 10,000, except for ABSAs 6 and 11 where cancer risks were at or above 1 in 100,000. For the single species scenario, cancer risks using maximum EPCs ranged from 8 in 100,000 to 5 in 10,000. For the multiple species scenario using average EPCs, cancer risks were all in the 1 in 10,000 range. For the multiple species scenario using maximum EPCs, cancer risks were all also in the 1 in 10,000 range. For the multiple species scenario, cancer risks using maximum EPCs ranged from 3 in 10,000 to 6.5 in 10,000.

As discussed in Section 5.3.1.1, risks were relatively high for ABSAs 1 and 2, although still much lower than those for site ABSAs (3 through 11). These areas, upstream of the source areas associated with the API/PC/KR site, may be influenced by non-site related sources of PCBs. Fish from ABSA 2, which includes Morrow Lake behind Morrow Pond Dam, have higher average and maximum PCB concentrations than fish taken from areas further upstream.

5.3.3.2 Noncancer Hazard

As presented on Tables 5-1 and 5-2 and Figures 5-5 through 5-8, all scenarios using both average and maximum EPCs exceeded a HQ of 1 for both the immunological and reproductive endpoints, except for ABSA 11 where the HQ for the reproductive endpoint was 0.8. The HQ for the average exposure point scenario ranged between 0.8 and 5 for reproductive endpoint and 3 and 18 for the immunological endpoint for single species. For mixed species, the HQ ranged between 2 and 5 for the reproductive endpoint and 8 and 17 for the immunological endpoint.

HQs for the maximum exposure point scenario ranged between 1 and 9 for the reproductive endpoint and 4 and 31 for the immunological endpoint for single species. For mixed species, HQs ranged between 4 and 11 for the reproductive endpoint and 15 and 38 for the immunological endpoint.

As discussed in Section 5.3.1.1, HQs for upstream ABSAs 1 and 2 are relatively high, suggesting some non-site related sources of PCBs above. HQs for ABSA 2 exceed the threshold of 1, although these HQs remain many times lower than those calculated for exposure in ABSAs 3 through 11.

5.3.4 Nearby Residents

5.3.4.1 Cancer Risks

As presented on Tables 5-3 and 5-4 and Figure 5-9, cancer risks for nearby residents in all three floodplain soil areas were in the 1 in 100,000 range using average EPCs and in the 1 in 10,000 or higher range using maximum EPCs. Estimates using maximum EPCs exceeded both MDEQ and EPA cancer risk thresholds; estimates using average EPCs exceeded MDEQ thresholds but were within EPA target cancer risk range. The highest risks using average EPCs were estimated for the Trowbridge area at 5 in 100,000; the highest risks using maximum EPCs were estimated for the Plainwell area at 3.5 in 10,000.

5.3.4.2 Noncancer Hazard

As presented on Tables 5-3 and 5-4 and Figure 5-10, noncancer HIs for the immunological endpoint in all three areas exceeded 1 using average and maximum EPCs. HIs using average EPCs ranged from 2 to 3 for the immunological endpoint and 0.6 to 0.8 for the reproductive endpoint. Estimates using maximum EPCs ranged from 8.5 to 20 for the immunological endpoint and from 2 to 6 for the reproductive endpoint.

5.3.5. Recreationalists

5.3.5.1 Cancer Risks

As presented on Tables 5-5 and 5-6 and Figure 5-11, cancer risks for recreationalists in all three floodplain areas were in the 1 in 1 million or higher range using average concentrations and in the 1 in 100,000 or higher range using maximum concentrations. Estimates using average concentrations were within EPA target risk range and below MDEQ threshold. Estimates using maximum concentrations were within EPA target risk range, but exceeded MDEQ threshold. The highest risks using average concentrations were estimated for the Trowbridge area at 5 in 1 million. The highest risks using the maximum concentrations were estimated for the Plainwell area at 4 in 100,000.

5.3.5.2 Noncancer Hazard

As presented on Tables 5-5 and 5-6 and Figure 5-12, using average EPCs, noncancer HIs for both the immunological and reproductive endpoints were below EPA and MDEQ threshold of 1. Using maximum EPCs, HQs for the reproductive endpoint were also all below the threshold of 1. Using maximum EPCs, HIs for the immunological endpoint exceeded the threshold of 1 for Plainwell (3), Otsego (1), and Trowbridge (2.5) areas.

5.4 Summary

Risks and hazard quotients/indices for the API/PC/KR site can be summarized as follows:

- Cancer risks and HQs in both central tendency and high end sport and subsistence anglers exceed EPA and/or MDEQ risk limits for all scenarios in all ABSAs in the API/PC/KR site using both average and maximum EPCs (with the exception of CTE sport anglers consuming 100 percent bass from ABSA 11 for which the calculated HQ based on average PCB concentrations was 0.8).

- Cancer risks for residents living near the floodplain soil behind the three MDNR impoundments exceed MDEQ thresholds using both average and maximum EPCs.

- Cancer risks for residents living near the floodplain soils behind the three MDNR impoundments are within EPA target cancer risk range but above the MDEQ threshold for the average scenario.

- Cancer risks for residents living near the floodplain soils behind the three MDNR impoundments are outside MDEQ and EPA target cancer risk range using maximum EPCs.

- HIs for residents living near the floodplain soils behind the three MDNR impoundments exceed MDEQ and EPA threshold of 1 for the immunological endpoint using both average and maximum EPCs. HQs for the reproductive endpoint do not exceed a HI of 1 using average EPCs. HIs using maximum EPCs exceed MDEQ and EPA threshold of 1.0 for the Trowbridge (5.5), Otsego (2), and Plainwell (6) areas.

- Cancer risks for recreationalists on the floodplain soil behind the three MDNR impoundments are within the EPA target risk range and less than MDEQ threshold using **average EPCs**.

- Cancer risks for recreationalists on the floodplain soil behind the three MDNR impoundments are within the EPA target risk range and exceed MDEQ threshold using **maximum EPCs**.

- HIs for recreationalists on the floodplain soil behind the three MDNR impoundments are less than EPA and MDEQ threshold of 1 for both the reproductive and immunological endpoints using average concentrations.

- HIs for recreationalists on the floodplain soil behind the three MDNR impoundments are less than EPA and MDEQ threshold of 1 for the reproductive endpoint using maximum EPCs. HIs for the immunological endpoint exceeded the threshold of 1 for the Trowbridge (2.5), Otsego (1), and Plainwell (3) areas using maximum EPCs.

- Some elevated cancer risk and hazard estimates were calculated for anglers in upstream ABSAs 1 and 2. These risks and hazards were many times less than those for ABSAs 3 through 11, but still suggest some smaller sources of PCBs above the Superfund site boundaries. Risks and hazards were highest for ABSA 2, which includes Morrow Lake behind Morrow Pond Dam.

Section 6
Determination of Risk-Based Sediment and Floodplain Soil Concentrations

Risk and hazard estimates associated with ingestion of fish and contact with floodplain soils have been developed and are presented in Section 5. Based on these estimates, risk-based fish concentrations (RBC_{fish}) and sediment concentrations (RBC_{sed}) for PCBs were developed to be protective of sport and subsistence anglers. Further, risk-based floodplain soil concentrations (RBC_{soil}) were developed to be protective of residents living near or recreating on exposed floodplain soil. RBCs were developed for both cancer and noncancer endpoints. Risk-based concentrations were developed using an allowable cancer risk of 1 in 100,000 and a noncancer hazard quotient/index of 1.0.

6.1 Calculation of Risk-Based Fish Concentrations

RBC_{fish} were developed using the same risk and hazard algorithms used to derive risk and hazard estimates (Figures 3-2 and 3-3). To derive RBCs, the algorithm is reversed to solve for the concentration in fish associated with a specified cancer risk or hazard quotient, in this case 1 in 100,000 cancer risk or a hazard of 1.0. RBC_{fish} were derived using the same assumptions regarding ingestion rates, reduction factors, exposure frequencies, and duration. Table 6-1 presents estimated RBC_{fish}. Appendix B provides spreadsheets for all RBC calculations.

Table 6-1 Risk-Based Fish Fillet Concentrations (RBC_{fish}) [1] API/PC/KR Site

Receptor	RBC_{fish} Protective of 1E-05 Cancer Risk for PCBs (mg/kg)	RBC_{fish} Protective of 1.0 Hazard Quotient for PCBs (mg/kg)
Sport Angler - Central Tendency Assumes 24 meals/year 0.015 kg/day	0.109	0.187
Sport Angler - High End Assumes 125 meals/year 0.078 kg/day [2]	0.042	0.072
Subsistence Angler Assumes 179 meals/year 0.11 kg/day	0.015	0.025

(1) Concentrations protective of both carp and smallmouth bass. Hazard quotient for immunological endpoint. Because RBC_{fish} based on immunological toxicity are lower than those based on reproductive toxicity, only RBC_{fish} for the immunological endpoint are presented.

(2) Value includes source fraction of 0.5. Central tendency and subsistence anglers are assumed to take all fish from the Kalamazoo River.

The RBC_{fish} protective of the central tendency sport angler consuming approximately 24 meals/year of fish, or an average daily ingestion rate of 0.015 kilograms/day (kg/day), is 0.109 mg/kg in fish fillet for the cancer endpoint and 0.187 for the noncancer endpoint (immunological). The RBC_{fish} protective of the high-end sport angler consuming up to 125 meals/year, or an average daily ingestion rate of

0.078 kg/day, is 0.042 mg/kg for the cancer endpoint and 0.072 for the noncancer endpoint. The RBC_{fish} protective of the subsistence angler consuming up to 179 meals/year, or an average daily ingestion rate of 0.11 kg/day, is 0.015 mg/kg protective for the cancer endpoint and 0.025 for the noncancer endpoint.

The MDCH has established criteria for placing fish on the Michigan Sport Fish Consumption Advisory. For the general population, when between 11 and 49 percent of samples exceed 2 mg/kg in fish, a one-meal/week advisory is issued; when greater than 50 percent of fish samples exceed 2 mg/kg, a no consumption advisory is issued. For women of childbearing age and children under 15 years of age, at concentrations greater than 0.05 mg/kg up to 0.2 mg/kg of PCBs in fish, a one-meal/week advisory is issued. At concentrations greater than 0.2 mg/kg, up to 1 mg/kg of PCBs in fish, a one-meal/month advisory is issued. At concentrations greater than 1.0 mg/kg up to 1.9 mg/kg of PCBs in fish, a six-meal/year advisory is issued. At concentrations above 1.9 mg/kg, a no consumption advisory is issued.

The MDCH considers their PCB fish advisory concentration of less than or equal to 0.05 mg/kg in fish to be protective at an ingestion rate of 225 meals/year (0.14 kg/day) for the general population for noncancer endpoints. The MDCH does not base its advisory on cancer risk, due to political and pragmatic considerations. For subsistence anglers, who have been reported to consume between three to four meals/week, the RBC_{fish} developed in this HHRA indicate that concentrations in the range of 0.015 mg/kg (cancer) and 0.025 mg/kg (noncancer) are needed to be protective of health. The differences between the derivations of the two noncancer values are listed in Table 6-2:

Table 6-2 Comparison of MDCH and HHRA Exposure Parameters

	MDCH	HHRA
Meals/year	225	179
Average daily fish consumption (kg)	0.14	0.11
Reduction by cleaning/cooking (%)	50	50
Weight of subject (kg)	70	70
Target dose, HPV or RfD (μg/kg/day)	0.05	0.02
PCB level in fish (mg/kg)	0.05	0.015

Most of the difference between the two results can be attributed to the difference between the health protection value (HPV) used by the MDCH (0.05 μg/kg/day) and the EPA RfD used in the HHRA (0.02 μg/kg/day). These values were derived from the same data by different methodologies. The Great Lakes Fish Advisory Task Force used a "weight of evidence" approach to derive the HPV used by the MDCH from data on a wide range of health effect endpoints. EPA derives RfDs from data on specific endpoints with uncertainty and modifying factors added.

The MDCH Division of Environmental Epidemiology has reviewed this document and considers it to be adequately consistent with the MDCH protocol for issuing fish consumption advisories. Although differences exist between RBC_{fish} and the MDCH first Level of Concern as cited above, MDCH considers that parameters and assumptions used in the two derivations are reasonable, the resulting levels to be reasonably close, and the RBC_{fish} levels to be more protective than the MDCH Level of Concern. MDCH acknowledges EPA and MDEQ's authority to establish the cleanup levels to be used at any site.

6.2 Calculation of Risk-Based Sediment Concentrations

The RBC_{fish} were used to develop RBC_{sed}. RBC_{sed} represent sediment concentrations protective of fish that are consumed at the ingestion rates specified for sport and subsistence anglers. In 1994, EPA Region V completed a draft guidance document, which presented an overview of available methods for developing RBCs and recommended the biota-to-sediment accumulation factor (BSAF) method. Three methods, the bioconcentration factor (BCF) method, the bioaccumulation factor (BAF) method, and the BSAF were evaluated. The BCF and BSAF methods relate fish tissue concentrations to water column concentrations and prey consumption whereas the BSAF method relates fish concentrations to sediment (Pelka 1998). Methods were tested by comparing predicted fish concentrations with actual fish data for four locations: Saginaw, Michigan; Buffalo, New York; Ontario, Canada; and Manistique, Michigan. EPA Region V determined that the BSAF approach consistently gave the most reliable estimates of fish concentration relative to other methods.

Guidance provided by EPA Region V on the BSAF approach was used to develop the risk-based concentrations for sediment. This approach has been described in Bioaccumulation Models and Applications: Setting Sediment Cleanup Goals in the Great Lakes (*Proceedings of the National Sediment Bioaccumulation Conference*, September 11-13, 1996, presented by Amy Pelka, EPA, Region V. EPA 823-R-98-002) and in other technical memorandum.

BSAFs and RBC_{sed} were calculated for each of seven ABSAs and site wide. BSAFs were based on lipid normalized fish fillet PCB concentrations and organic carbon normalized sediment concentrations. RBC_{sed} were calculated based on a range of RBC_{fish} developed in the HHRA. To understand the uncertainty associated with the normalized data, and to estimate 95% confidence limits, a "bootstrapping" approach was used (Efron 1982). This approach involved random sampling with replacement from the underlying data on an ABSA-by-ABSA (or reach by reach) and species fillet basis and calculation of the BSAF and RBC_{sed} for each of these data subsets. This process was repeated 5,000 times to generate an estimate of the sampling distribution of BSAFs and RBC_{sed} by fish species, river reach, and site wide. This method used data only when PCB and TOC data were available for the same sediment sample, and PCB and % lipid from the same fish fillet. Tables 6-3 and 6-4 present the results of this analysis along with applicable summary statistics for smallmouth bass and carp.

The tables present the results on an ABSA-by-ABSA basis as well as a sitewide basis. No biological, physical, or chemical basis has been identified that would suggest that BSAFs would be greatly different among ABSAs for the BSAF to vary greatly among stream reaches. Differences in BSAF probably represent variability in measurements and uncertainties in the BSAF model. Thus, for risk assessment purposes, pooled data from all areas was used for final calculations of RBC_{sed}. The full analysis and description of the bootstrapping algorithm are presented in Appendix A.

Table 6-3 Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site Human Health Risk Assessment Biota/Sediment Accumulation Factors, Bootstrap Distributions of BSAF for Smallmouth Bass

ABSA	BSAF[1]	Bootstrap BSAF Distribution			
		Mean	Median	LCL95	UCL95
3	0.296	0.314	0.301	0.182	0.515
4	0.604	0.669	0.620	0.343	1.261
5	0.432	0.638	0.443	0.194	1.916
6	0.092	0.208	0.099	0.028	0.891
7	0.371	0.470	0.393	0.183	1.161
8	2.296	2.590	2.373	1.303	5.148
9	0.708	0.755	0.723	0.438	1.249
Sitewide Average of ABSAs	0.686	0.806	0.707	0.382	1.735
Sitewide Average all fish and sediment pooled	0.444	0.456	0.449	0.307	0.643

1 BSAF calculated as ($PCB_{fish\ fillet}$/ % lipid)/ (PCB_{sed}/ % TOC)

Table 6-4 Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site Human Health Risk Assessment Biota/Sediment Accumulation Factors, Bootstrap Distributions of BSAF for Common Carp

ABSA	BSAF[1]	Bootstrap BSAF Distribution			
		Mean	Median	LCL95	UCL95
3	0.523	0.557	0.536	0.302	0.939
4	1.113	1.235	1.155	0.636	2.298
5	0.313	0.466	0.332	0.143	1.455
6	0.202	0.463	0.219	0.068	1.954
7	0.275	0.341	0.288	0.124	0.861
8	3.437	3.854	3.506	1.807	7.990
9	0.935	0.991	0.950	0.554	1.677
Sitewide Average of ABSAs	0.971	1.130	0.998	0.519	2.453
Sitewide Average all fish and sediment pooled	0.641	0.661	0.651	0.439	0.949

1 BSAF calculated as ($PCB_{fish\ fillet}$/ % lipid)/ (PCB_{sed}/ % TOC)

Sitewide BSAFs for carp and smallmouth bass were calculated for the API/PC/KR site. Using synoptic data for fish and sediment, BSAFs of 0.456 and 0.661 were derived for smallmouth bass and carp, respectively (Spectrum Consulting Services 2001). BSAFs were calculated as

$$\mathbf{BSAF = (PCB_{fish\,fillet} / \%\,lipid) / (PCB_{sed} / \%\,TOC)}$$

Using site-specific BSAFs, the following equation can be used to derive RBC_{sed}:

$$\mathbf{Concentration_{sediment} = (toc * RBC_{fish}) / (BSAF * \%\,lipid)}$$

Where: Sitewide TOC (total organic carbon) = 0.0279%
Sitewide BSAF 0.444 (bass); 0.641 (carp)
Sitewide lipid 0.013 (bass); 0.0358 (carp)
Risk-based fish concentrations =
0.109 (mg/kg) central tendency sport
0.042 (mg/kg) high end sport anglers
0.015 (mg/kg) subsistence anglers
Hazard-based fish concentrations, based on immunological endpoint =
0.187 (mg/kg) central tendency sport anglers
0.072 (mg/kg) high end sport anglers
0.025 (mg/kg) subsistence

RBC_{sed} are presented in Table 6-5. RBCs are different depending on the species consumed. For the central tendency sport angler, if ingestion of only smallmouth bass is assumed, the RBC_{sed} is 0.51 mg/kg for the cancer endpoint and 0.88 mg/kg for the noncancer endpoint (immunological). If ingestion of a combination of smallmouth bass and carp is assumed, the RBCsed is 0.30 mg/kg for the cancer endpoint and 0.52 mg/kg for the noncancer endpoint.

For the high end sport angler, if ingestion of smallmouth bass is assumed, the RBC_{sed} is 0.20 mg/kg for the cancer endpoint, 0.34 mg/kg for the noncancer endpoint. If ingestion of a combination of smallmouth bass and carp is assumed, the RBCsed is 0.12 mg/kg for cancer endpoints and 0.20 for the noncancer endpoint.

Table 6-5 Risk-Based Sediment Concentration (RBC_{sed}) API/PC/KR SITE

Scenario	RBC_{sed} Protective of Fish Ingestion at 1E-05 Cancer Risk for PCBs (mg/kg)		RBC_{sed} Protective of Fish Ingestion at 1.0 Hazard Quotient for PCBs (mg/kg)	
	Bass	Bass/Carp	Bass	Bass/Carp
Sport Angler - Central Tendency	0.51	0.30	0.88	0.52
Sport Angler - High End	0.20	0.12	0.34	0.20
Subsistence Angler	0.07	0.04	0.12	0.07

For the subsistence angler, if ingestion of smallmouth bass is assumed, the RBC_{sed} is 0.07 mg/kg for the cancer endpoint and 0.12 mg/kg for the noncancer endpoint. If ingestion of a combination of smallmouth bass and carp is being protected, the RBC_{sed} is 0.04 for the cancer endpoint and 0.07 mg/kg for the noncancer endpoint.

6.3 Calculation of Risk-Based Soil Concentrations

The risk-based floodplain soil concentration (RBC_{soil}) were derived in the same manner as the RBC_{fish}, i.e., the risk and hazard algorithms were reversed and were solved using a cancer risk of 1 in 100,000 and a hazard index of 1.0. The same exposure assumptions used to estimate risk and hazard were used to derive RBC_{soil}.

Table 6-6 presents RBC_{soil} protective of residents. RBC_{soil} protective of residents for the cancer endpoint is 2.5 mg/kg. For noncancer endpoints, RBC_{soil} is 15 mg/kg for the reproductive endpoint and 4 mg/kg for the immunological endpoint.

Table 6-6 Risk-Based Floodplain Soil Concentrations (RBC_{soil}) Protective of Residents API/PC/KR Site

Receptor	RBC_{soil} Protective of 1E-05 Cancer Risk (mg/kg)	RBC_{soil} Protective of 1.0 Hazard Index (mg/kg)
Resident	2.5	15 (R) 4.0 (I)

Notes (R) = Reproductive endpoint
(I) = Immunological endpoint

Table 6-7 presents the RBC_{soil} protective of recreationalists. For the cancer endpoint the RBC_{soil} is 23 mg/kg. For noncancer endpoints, the RBC_{soil} is 139 mg/kg for the reproductive endpoint and 32 mg/kg for the immunological endpoint.

Table 6-7 Risk-Based Floodplain Soil Concentrations (RBC_{soil}) Protective of Recreational Visitors API/PC/KR Site

Receptor	RBC_{soil} Protective of 1E-05 Cancer Risk (mg/kg)	RBC_{soil} Protective of 1.0 Hazard Index (mg/kg)
Resident	23	139 (R) 32 (I)

Notes: (R) = Reproductive endpoint
(I) = Immunological endpoint

Appendix A presents the spreadsheets used to derive RBCs.

6.4 Applicability of RBC_{sed}

RBC_{sed} calculated for protection of angler assume that sediments are in-stream, or could reasonably become in-stream due to erosion or flooding. RBC_{sed} also assume a wide range of fish consumption for the three angle scenarios. Different angler scenarios could conceivably apply to different stream reaches, since angling success may vary significantly among ABSAs. For example, ABSA 9, Lake Allegan, appears to be a poorer fishery than other reaches of the river system. Data do not appear to be available, however, to allow a quantitative approach to different fishing behavior in different stream reaches.

RBC_{sed} calculated to protect residents might apply most directly to those areas immediately adjacent to former impoundment areas that could be visited on an almost daily basis by people living on the edge of the floodplain. Observations for some homes and yards that are located on adjacent to floodplain soils indicate the potential for ongoing exposure.

RBC_{sed} may be applicable anywhere in the floodplain where exposed soils/sediments contaminated with paper waste exist. The focus of the risk assessment for recreational exposures was on the former impoundment areas, and these areas may well represent most of the more attractive recreational areas with exposed contaminated soils/sediments within the site. However, RBC_{sed} for recreational exposures would be equally applicable to accessible sites where contaminated exposed soils/sediments exist anywhere along the river.

6.5 Comparison of RBC Based on Human Health and Ecological Risk

CDM (2001) prepared a comprehensive ecological risk assessment (ERA), based on many of the same site data, as a companion to this HHRA. This ERA also develop a range of RBC for several important receptors. The range of RBC based on protection of riverine and upland species, is not greatly different than the range of RBC developed based on risks and hazards to human health. For all sediments that can be assumed to be part of the aquatic environment, RBCs based on protection of mink range from 0.5 to 0.6 mg/kg (Figure 6-1). The range in Table 6-4, from 0.04 mg/kg (subsistence angler, cancer endpoint, bass/carp diet) to 0.88 mg/kg (sport angler CTE, immunological endpoint, bass only diet), overlaps substantially with this range. Protection of both human and ecological receptors can apparently be achieved for pathways associated with contamination of aquatic habitats using much the same target sediment values.

Similarly, the range of RBC for protection of upland species (great horned owl, robin, mouse, and fox) range from 2.9 to 63 mg/kg (Figure 6-2). Again this range overlaps to a great extent with the range of values in Tables 6-5 and 6-6 (2.5 to 139 depending on receptor and toxicological endpoint). If a decision is made to manage risk for exposed floodplain soil on some basis other than as a source to river sediment, again, protection of human and ecological receptors might be achieved with similar target soil/sediment concentrations.

Figure 6-1

Figure 6-2

Protective Threshold Sediments/Surface Water PCB Concentrations for Mink
Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site

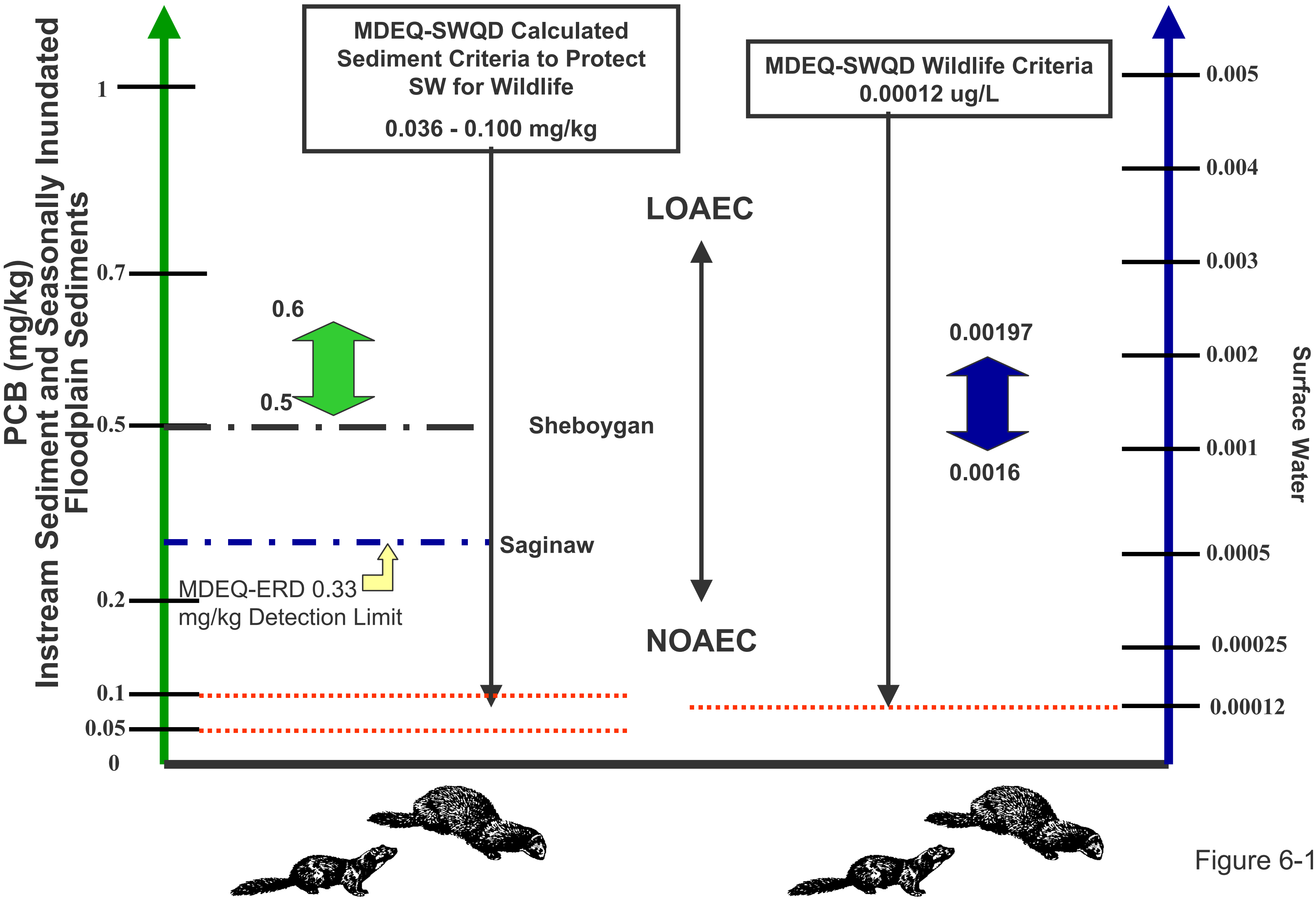
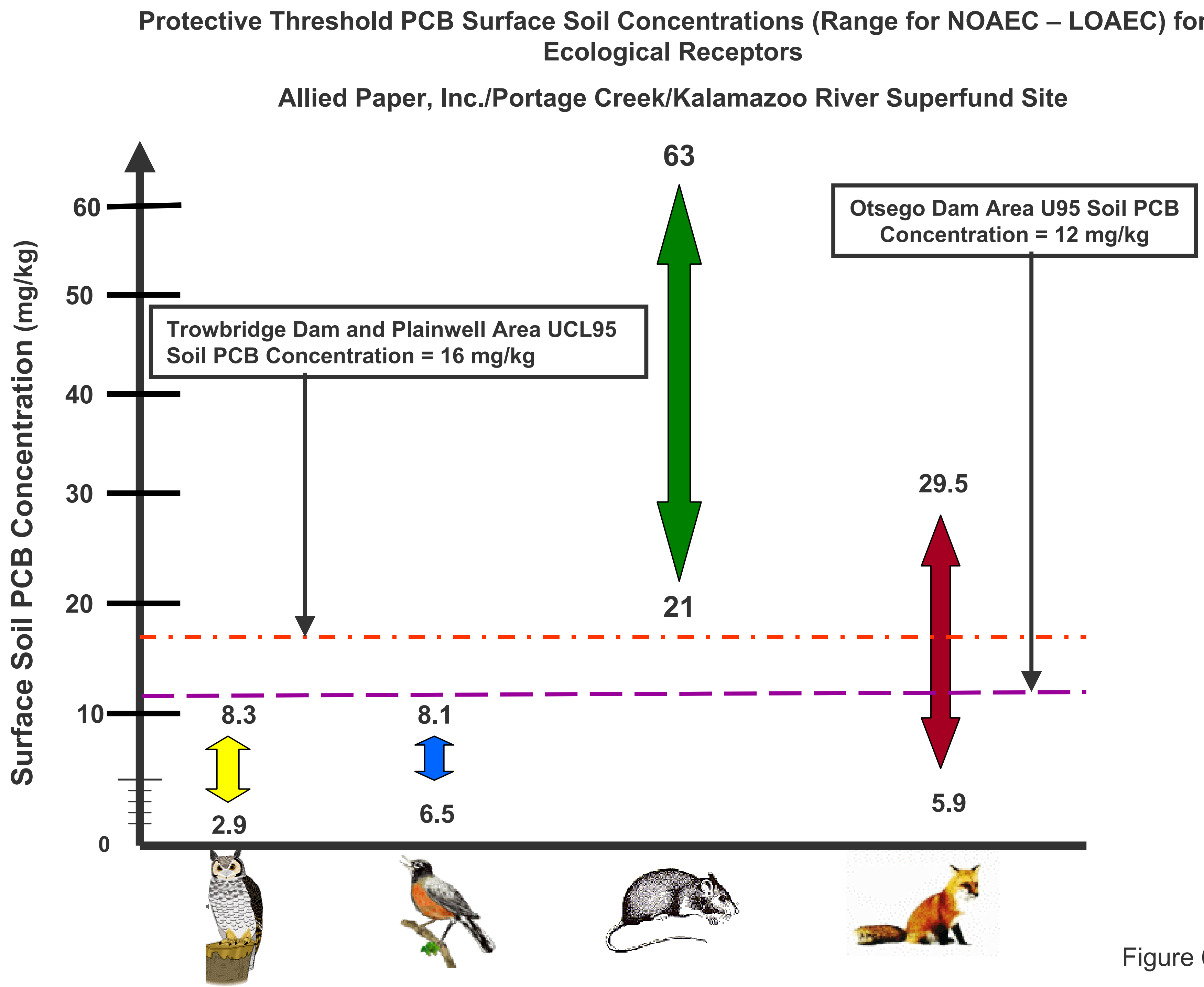


Figure 6-1



Protective Threshold PCB Surface Soil Concentrations (Range for NOAEC – LOAEC) for Ecological Receptors
Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site
Surface Soil PCB Concentration (mg/kg)
60
50
40
30
20
10
0
63
21
Otsego Dam Area U95 Soil PCB Concentration = 12 mg/kg
Trowbridge Dam and Plainwell Area UCL95 Soil PCB Concentration = 16 mg/kg
29.5
5.9
8.3
2.9
8.1
6.5

Figure 6-2

Section 7
Uncertainty Assessment

Uncertainties can arise from several sources in a human health risk assessment including data collection and interpretation, assumptions used to characterize exposures, and toxicity values. To compensate for uncertainty surrounding input variables, conservative assumptions are often made that tend to overestimate rather than underestimate risk. In cases where data are limited, assumptions may be based on professional judgment or subjective estimates that may under or over estimate risks.

7.1 Types of Uncertainty

Three primary sources of uncertainty include:

- Scenario uncertainty
- Parameter uncertainty
- Model uncertainty

Scenario uncertainty results from missing or incomplete information needed to fully define exposure and dose. This uncertainty may include errors or gaps in site characterization, professional judgment, assumptions regarding exposed populations, and steady-state conditions. Sources of parameter uncertainty include measurement and sampling errors, inherent variability in environmental and exposure-related parameters, and the use of generic surrogate data or default assumptions when site-specific data are not available. Parameter uncertainty often leads to model uncertainty. One source of modeling uncertainty is relationship errors, such as errors in correlations among chemical properties or limitations in mathematical expressions used to define environmental processes. Errors due to the use of mathematical or conceptual models as simplified representations of reality are also sources of modeling uncertainty.

Often analysis of uncertainties is divided in "true uncertainty" and "variability." The former is uncertainty due to lack of knowledge of data. Variability is uncertainty due to unresolvable variation in physical, chemical, and biological process, human behavioral patterns, seasonal changes, and data for site characterization. An example of uncertainty in this HHRA involves selection of an exposure frequency for recreational site users. No site-specific information is available and this parameter is based on professional judgment.

An example of variability in this HHRA involves BSAF estimates derived from sediment, TOC, fish fillet, and percent lipid data. These estimates are based on a large amount of site-specific data and are likely to reflect unresolvable variation in this parameter.

These three types of uncertainty have been identified in each of the four parts of this risk assessment: data evaluation, toxicity assessment, exposure assessment, and risk characterization. Uncertainty within each of these components is discussed below.

7.2 Data Evaluation

Uncertainty is present in the data before it is even evaluated for risk assessment. This includes potential sampling bias, errors in laboratory extraction and analysis, and the protocol employed to assess contaminants identified as nondetected. A higher level of confidence is placed on the analytical results. Sampling errors and biases and assumptions for use of nondetect data are almost always more important from uncertainty considerations.

Fish data used to assess risks were collected in 1993 and 1997, and exposed floodplain data were collected in 1994. Because one of the primary sources of PCBs to the River is erosion of material from the riverbanks, and this source is ongoing, levels of PCBs detected in aquatic biota may have not significantly declined in the intervening period. Further, based on the persistence of PCBs, and in the absence removal actions, significant chemical degradation or other means of PCBs is not expected to be significant for floodplain soil. For these reasons, the data used to characterize the risk and hazards associated with ingestion of fish and contact with floodplain soil are deemed appropriate. The use of these data is unlikely to have resulted in a significant underestimation or overestimation of risks and hazards. Still, data are scant or absent for evaluating these assumptions.

Data for two media were deemed inadequate to conduct a quantitative risk evaluation. Turtle consumption is a confirmed exposure pathway for the Kalamazoo River; however, turtle consumption is expected to be less than fish consumption for the majority of people. The risks and hazards associated with fish ingestion provide a conservative estimate of the risks and hazards associated with turtle consumption. The absence of quantified risks and hazards resulting from turtle ingestion likely results in an underestimation of total site risks and hazards.

Air data have not been collected in the immediate vicinity of the River or exposed floodplain areas. Data collected from the Willow Boulevard / A-Site operable unit are not representative of the conditions in the immediate vicinity of the floodplain where soils are unvegetated and prone to entrainment. Concentrations of volatile emissions and particulates above the floodplain soil have been estimated using a simplified model and risks and hazards associated with this pathway were quantified. In the absence of actual air data, whether risks and hazards are underestimated or overestimated cannot be determined.

Air quality above surface water has not been characterized. Inhalation of volatile emissions above surface water was found to be associated with significant risks for the Lower Fox River Site (ThermoRetec 1999). In the absence of actual data and quantitative estimates of risks and hazards for this pathway, total site risks and hazards are likely underestimated.

Data from another site were used to verify that exposures to surface water would not result in significant risks or hazards. Uncertainties associated with these data also apply to the API/PC/KR Site. Since these data have been thoroughly evaluated, uncertainties are assumed to be manageable. More recent data indicate surface water quality data reported in Technical Memorandum 16 – Surface Water Investigation (BB&L) were comparable to data collected from the Lower Fox River.

A concern exists relative to the overall site characterization in terms of whether the appropriate number of samples was taken in the appropriate areas (geospatial relationships of PCBs in sediments and exposed soils). In this risk assessment, mean sediment concentration is a critical input to the HHRA. There are three important issues related to site characterization that could affect the HHRA:

1. Are there adequate data to reliably estimate mean PCB concentrations in surficial sediment?

2. What is the best estimator of mean PCB concentration in sediment?

3. Is bootstrap sampling a valid approach to estimate the sampling distributions of BSAF and RBCs?

These issues are discussed in detail below.

1. Surficial sediment samples from a total of 630 individual locations were used to estimate TOC normalized PCB concentrations at the site. The sample locations were based on 120 transects across the floodplain. The transects show that the concentrations of PCBs vary widely throughout the floodplain. For reach-specific calculations, sample sizes ranged from more than approximately 30 locations to over 160 locations. These data provide adequate sample size to estimate reach-specific and sitewide average PCB concentration.

2. The sample average was used to estimate the spatial average of PCB concentration in surficial sediment. This is justified because the best estimator of the spatial average, among all unbiased linear estimators, is the ordinary block kriging estimator (Cressie 1991, p. 124) and when sample data are either systematically sampled, or uncorrelated, the block kriging estimator simplifies to the usual sample average (i.e., each of the samples receive equal weights). Because the sampling design for instream sediment at the Kalamazoo River is reasonably systematic, and because the data are very weakly autocorrelated, the sample mean is appropriate to estimate the spatial mean of PCB concentration in surface sediments. Although other unbiased estimators are possible, they will be less precise (i.e., less reliable sampling distributions). Using block kriging to estimate spatial means over large areas was first discussed by Journel and Huijbregts

(1973). Kern and Coyle (2000) compare the block kriging and sample average estimators for autocorrelated data and also discuss algorithms and software to estimate the block kriging estimator for large data sets on irregularly shaped areas such as rivers. Most commonly available software packages do not provide such routines.

3. The bootstrap analysis used for the estimation of RBCs, as presented in Section 6, requires that either the sample data are statistically independent in a model based sense (i.e., little or no autocorrelation among sample locations), or that the data were sampled using a randomized design (regardless of the autocorrelation in underlying data), such as a systematic sample with a random starting point or a simple random sample. The sediment data were not collected using a randomized design; however, the design is reasonably close to systematic. Variogram analysis conducted as part of the geostatistical pilot study (Technical Memorandum 10) indicate that sample locations on adjacent transects located one to several thousand feet apart are uncorrelated, and that samples at adjacent locations on a single transect may be very weakly correlated. Given the large sample sizes, the bootstrap algorithm is expected to be robust to the minor departure from assumptions associated with weak spatial dependence. The systematic nature of the sampling design is nearly adequate to justify the bootstrap algorithm even for strongly autocorrelated data. As previously stated, the concentrations of PCBs vary widely across and among transects, justifying the use of bootstrapping.

Other issues related to site characterization such as documentation of extent, estimation of volume, and small-scale patterns in PCB distribution are not likely to affect estimates of human health risk. Data used to prepare this report are adequate both in terms of location and number of samples to estimate risk to human health. EPA is planning to conduct additional sampling in one or two areas of the river to validate the current data set. However, it is unlikely that the results of this sampling effort will substantially affect the final estimates of human health risks and hazards.

7.3 Dose-Response Assessment

The dose-response section involves the estimation of the toxicological effects of a compound on humans usually based upon laboratory animal studies. A potentially significant source of uncertainty occurs when dose-response relationships in humans are derived from animal to human extrapolation. These associates often result from high-dose to low-dose extrapolations as well. Health effects criteria are derived with margins of safety relative to the degree of uncertainty in the value.

Noncancer toxicity values and cancer slope factors have been derived from studies of commercial mixtures. After release into the environment, PCB mixtures change over time so their composition differs from commercial mixtures. Through partitioning, different fractions of the original mixture appear in the air, water, sediment, soil, and biota due to different rates of volatilization, solubility, and adsorption for the congeners. (EPA 1996). Bioaccumulation through the food chain tends to concentrate congeners of higher chlorine content, producing residues that are considerably different from the original aroclors (Cogliano 1998). Both humans and animals retain persistent congeners that are resistant to metabolism and elimination (Oliver and Niimi 1988). Mink fed Great Lakes fish contaminated with PCBs showed liver and reproductive toxicity comparable to mink fed Aroclor 1254 at quantities three times greater (Hornshaw 1983). PCBs tested in the laboratory were not subject to prior selective retention of persistent congeners through the food chain. For exposures through the food chain in most environmental situations, risks are probably higher than those estimated using toxicity values and cancer slope factors based on commercial mixtures (EPA 1996). Risk and hazard estimates for the fish ingestion pathway are likely underestimated. However, congener-specific data are not available to determine the magnitude of effects due to differing environmental fates of various PCB congeners.

7.4 Exposure Assessment

The exposure assessment step involves many assumptions about "typical people" and "typical exposure scenarios" to arrive at an average daily dose. For example, a body weight of 70 kg is used for residents and anglers. Body weight ranges for each individual, so these assumptions likely overestimate or underestimate the true dose that people are likely to receive.

Many exposure factors were chosen to err on the side of protectiveness for human health. Exposure duration, frequency, and time were set at reasonable maximum exposure values. They likely overestimate the exposures that typically occur.

The computation of the exposure point concentration for chemicals in a number of media may have resulted in an overestimate or underestimate of risks and hazards. Averages of site data exposure point concentrations may underestimate risks and hazards for some receptors while use of the maxima from site data exposure point concentration may overestimate risks and hazards for some receptors. Risks and hazards from both types of EPCs are provided in this assessment to try to bracket potential site-related impacts.

Another assumption made in this assessment is that exposure to study chemicals in various media remains constant over time. This suggests there is a nondiminishing source of contamination and that concentrations will remain at present levels for up to 30 years. In reality, soil, sediment, surface, and groundwater migrate. This would produce an exposure significantly less than that calculated in this assessment.

Another assumption made in the assessment is that a target hazard quotient of 1.0 (HI is not applicable, since only one contaminant, PCBs, and one exposure route, ingestion of fish, was considered for angler receptors) was used to calculate the RBC_{fish}. This is a deviation from MDEQ Surface Water Quality Division guidance, which specifies that a hazard index of 0.8 be used to calculate the RBC_{fish}. The MDEQ guidance is intended to be protective of noncancer endpoints based on a relative source contribution factor of 0.8. The relative source contribution factor accounts for the fact that exposures to PCBs may occur from activities other than those which are site-related. The difference between a hazard index of 1.0 and 0.8 is minimal and should not greatly influence the RBC values.

The exposure assumption with the greatest influence on risk and hazard is the fish ingestion rate. Three ingestion rates were chosen to reflect the central tendency sport angler, the high-end sport angler, and cancer risk estimates and hazard quotient estimates. The lowest ingestion rate of 15 grams/person/day, which was used to characterize risks and hazards to the central tendency sport angler, was derived from the Great Lakes Water Quality Initiative Technical Support Document for Human Health Criteria and Values (EPA 1995b). This ingestion rate is consistent with the mean ingestion rate for anglers reported in both the Kalamazoo River Angler Survey (MDCH 1998), and Fish Consumption Estimates Based on the 1991-1992 Michigan Sport Anglers Fish Consumption Survey (EPA 1995c). A significant number of anglers ingest greater quantities of fish, therefore, the central tendency estimates under-represent risks and hazards to these individuals. Fish consumption advisories are intended to reduce the ingestion of contaminated fish. If fish consumption advisories are reducing consumption, reported consumption levels will be suppressed from their normal levels (West 1993). Of a total of 1,347 respondents to the Michigan sport anglers consumption study, 46.8 percent reported to have eaten less fish in response to advisory warnings. In the Kalamazoo River Anglers Survey, 25 percent of respondents indicated they would make more trips to the River and fewer to other locations if the River was cleaned up to the point that fish advisories were removed; 15 percent of respondents indicated they would increase fishing in the Kalamazoo River without reducing trips to other bodies of water. This consumption suppression effect can result in an underestimate of risks and hazards for assumed baseline conditions, i.e., in the absence of remediation or risk reduction measures such as fish advisories.

Figures 7-1 and 7-2 show relative impacts of composition of fish (bass only versus a combination of bass and carp) consumed by anglers on cancer risk estimates and hazard quotient estimates for the high-end sport angler. These figures also illustrate the relationship between risk and hazard based on maximum and average fish fillet concentrations. Cancer risks for consumption of both bass and carp (trophic level 4 and 3 fish respectively), show a variety of patterns among different ABSA. For ABSAs 3,4 and 5, 10 and 11, consumption of both bass and carp is associate with significantly higher risk and hazard than consumption of bass only. In contrast, much smaller differences are seen for ABSA 6, 7, and 8. For ABSA 9, Lake Allegan, almost no difference is noted. These results probably reflect variability in data, but could also reflect differences in habitat that produce different levels of exposure for fish in different ABSAs. Data are insufficient to resolve such issues at present.

Comparison of Cancer Risks Based on Maximum and Average Fillet Concentrations for Bass Only and Bass/Carp Consumption High End Sport Angler

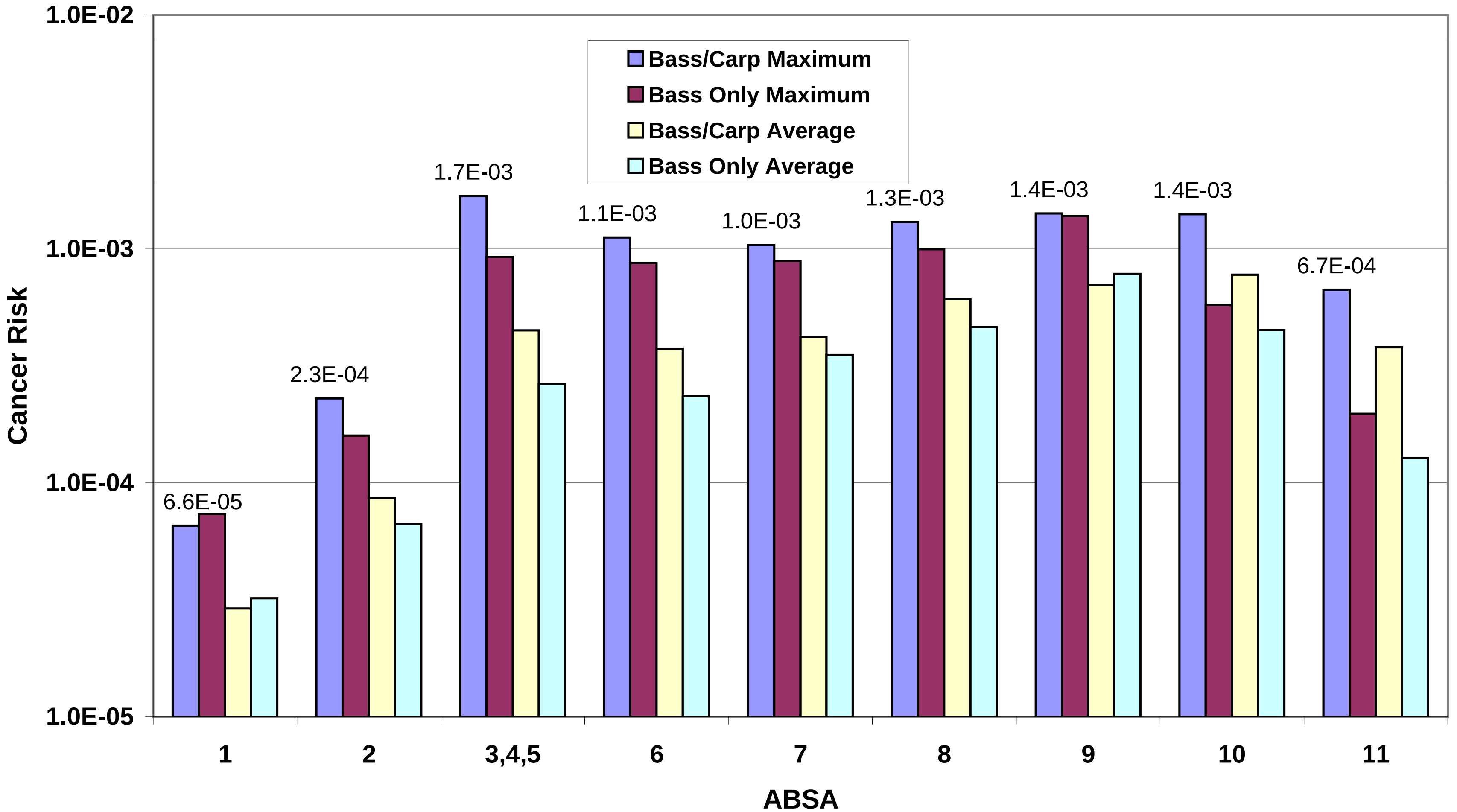


FIGURE 7-1

API/PC/KR SITE

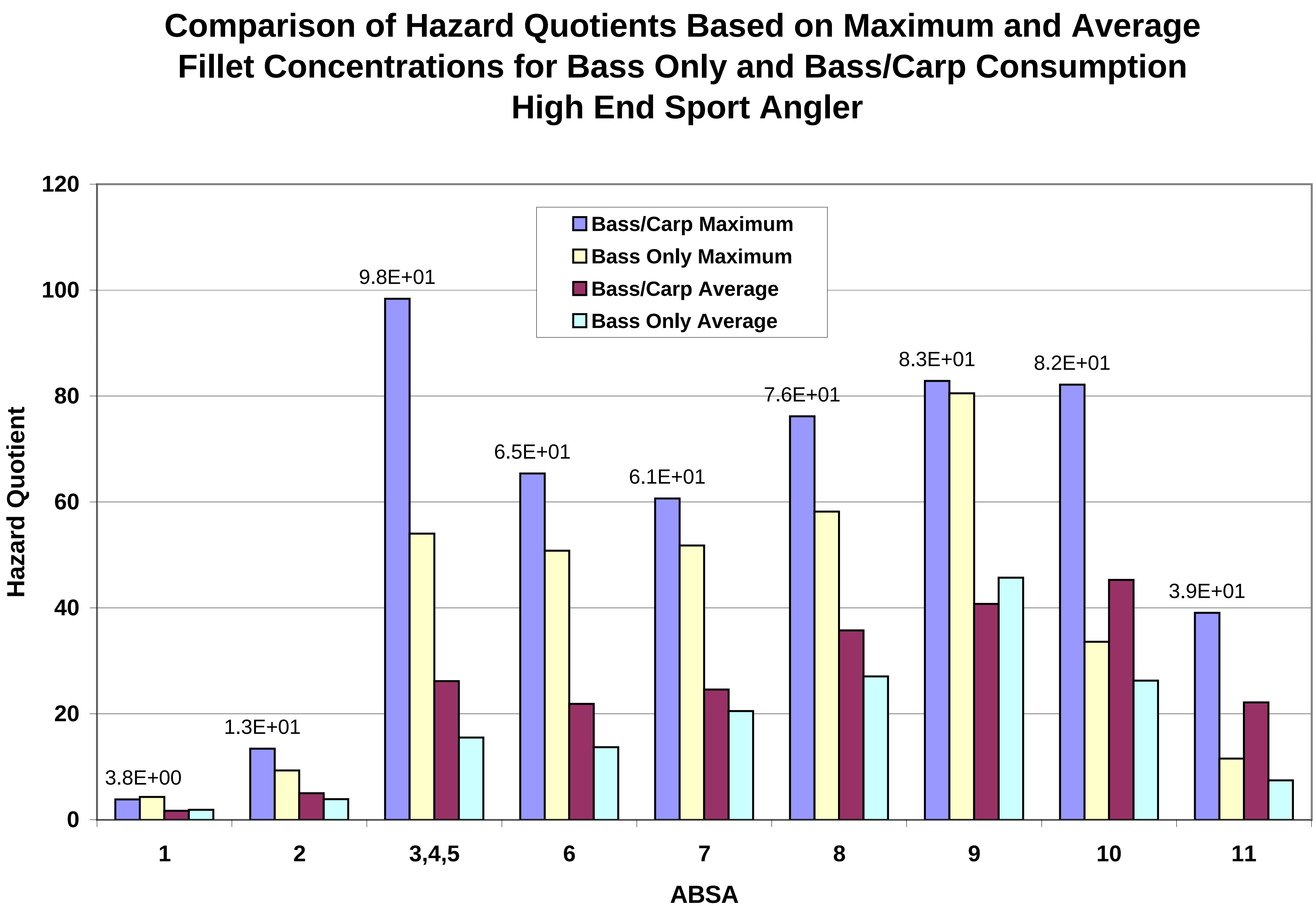


FIGURE 7-2

API/PC/KR SITE

Figures 7-1 and 7-2 also illustrate differences between average and maximum concentrations of PCB in fish fillets. Generally, these two values are substantially different, and risk management decisions based on one or the other value could result in different actions for the site. At present the small sample sizes (generally 11 fish of each species per ABSA) are not sufficient to provide long term estimates of average concentrations. Long-term averages would best reflect potential exposure for the scenarios addressed in this assessment. Currently, trends in fish tissue concentrations are being analyzed; these analyses may help address the issue of the applicability of risk estimates based on average and maximum concentrations.

The second most influential assumption for the fish ingestion scenario is the portion of fish caught from the contaminated source. For central tendency high-end sport anglers and subsistence anglers it was assumed that all of the fish ingested came from a particular ABSA. For high end sport anglers it was assumed half of the fish ingested came from a particular ABSA. Risks and hazards could be underestimated for those high-end anglers who catch all of their fish from different locations within the API/PC/KR site.

A reduction factor was used to account for the loss of PCBs when fish is cooked. This reduction factor did account for PCB losses during trimming fish and removing fat. Data reported in the Kalamazoo River Anglers Survey indicates that about 65 percent reported some trimming and skin removal prior to cooking.

The Michigan Sport Anglers Study also reported that between 44 and 84 percent of anglers did trim the fat from sport fish prior to cooking. For these reasons, use of a 50 percent overall reduction factor is believed to be appropriate for a large fraction of the population.

Residential exposure assumptions could overestimate risk for impoundment areas that are not readily accessible to residents. A recreational exposure scenario has been developed in an attempt to quantify exposure in hard-to-reach areas. However, application of the residential and recreational exposure scenarios is subject to a variety of considerations, including: (1) future risk is generally considered, and residential development may expand beyond current boundaries decreasing the area to which a recreational scenario would apply; and (2) the dynamic nature of the river system makes application of conservative assumptions appropriate. Periodic flooding may transport sediments from one area of an impoundment to another. Soils to which a recreational scenario is applied could be transported to an area where residential exposure is likely.

7.5 Risk Characterization and Calculation of RBCs

Assumptions are made using best professional judgment and the scientific literature on site risk assessments. In general, assumptions made throughout this risk assessment are conservative in that they tend to overestimate exposure and resultant risk rather than underestimate it. The overall risk to public health attributable to the site is an upper-bound probability of adverse health effects. True health effects may be lower. However, it should be noted that the individual errors from different sources might be propagated into larger errors by mathematical manipulation in the risk assessment.

Some quantification of variability associated with estimated RBC_{sed} can be developed using the results of the bootstrapping procedure discussed in Section 6.2. Bootstrapping was used to estimate both mean and upper and lower 95 percent confidence limits for BSAF. Mean BSAF estimates were used to calculate RBC_{sed} developed in Section 6.2. RBC_{sed} can also be calculated using upper and lower confidence limits to provide an indication of the range of RBC that could be considered in risk management of the site. Figures 7-3 and 7-4 illustrate these ranges for RBC_{sed} for cancer and noncancer (immunological) endpoint respectively.

Confidence intervals for RBC_{sed} based on cancer risk overlap for the Sport Angler - CTE and Sport Angler - High End, and for the Sport Angler - High End and Subsistence Angler (Figure 7-3). One might reasonably conclude that selection of a target clean-up level within the regions of overlap could be protective for many or most anglers in either category.

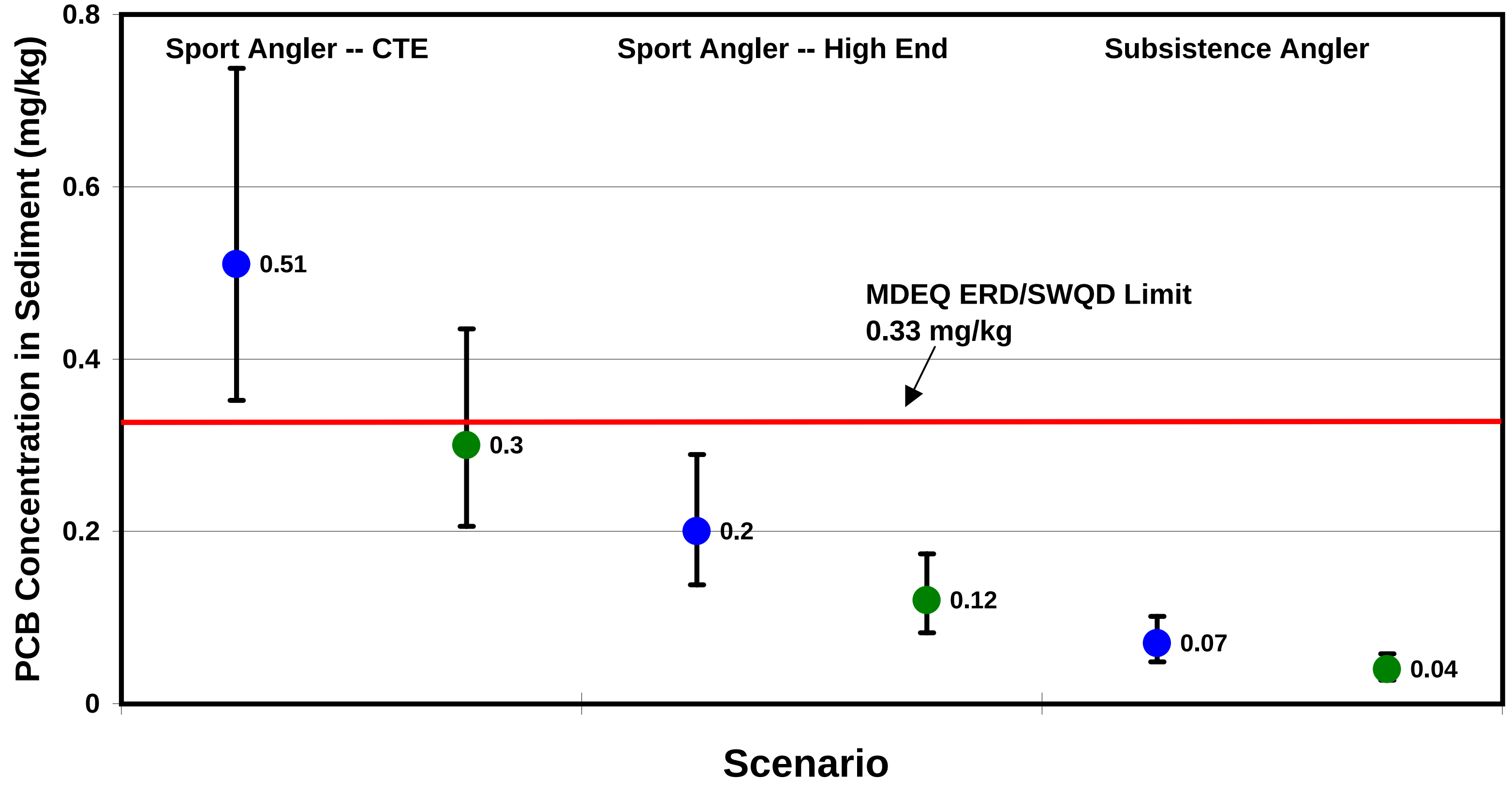
RBC_{sed} and associated confidence limits are generally lower than the MDEQ ERD/SWQD "detection limit" of 0.33 mg/kg for sediment. Actually, lower detection limits can be achieved in many samples; 0.33 is considered by the State to be a detection limit than can be reliably achieved in virtually all samples with PCB concentrations in the range of those commonly seen in riverine systems.

RBC_{sed} and associated confidence intervals are somewhat higher when based on noncancer (immunological) health concerns (Figure 7-4). Confidence intervals still overlap among scenarios. However, RBC_{sed} are higher than the MDEQ ERD/SWQD limit of 0.33 mg/kg in many cases. In fact, only ranges of RBC_{sed} for the subsistence angler are not higher than, or overlapping with this limit.

Variability in BSAF does suggest a range of estimated RBC_{sed} that represents possible protective clean-up targets for the API/PC/KR Site. One should note, however, that confidence intervals illustrated in Figures 7-3 and 7-4 do not consider many sources of uncertainty other than those associated with BSAF estimation. If these sources of uncertainty (many of which are discussed above) were evaluated quantitatively, confidence intervals about RBC_{sed} would widen. Widening of confidence intervals would increase overlap of possible clean-up targets among scenarios. One should not, therefore, assume that a target clean-up goal that exceeds the upper confidence limit for RBC_{sed} for any angler population would necessarily be nonprotective for all members of the population.

Risk assessment guidance (EPA 1989) stresses the importance of considering uncertainties in interpreting and applying results of any risk assessment. Thus, RBC_{sed} with associated confidence intervals as presented in Figures 7-3 and 7-4 may be the most appropriate for consideration in risk management for the site.

Confidence Intervals for Risk-Based Concentrations Based on Variability in BSAF
RBC_{sed} Based on Cancer Risk Target of 1 in 100,000

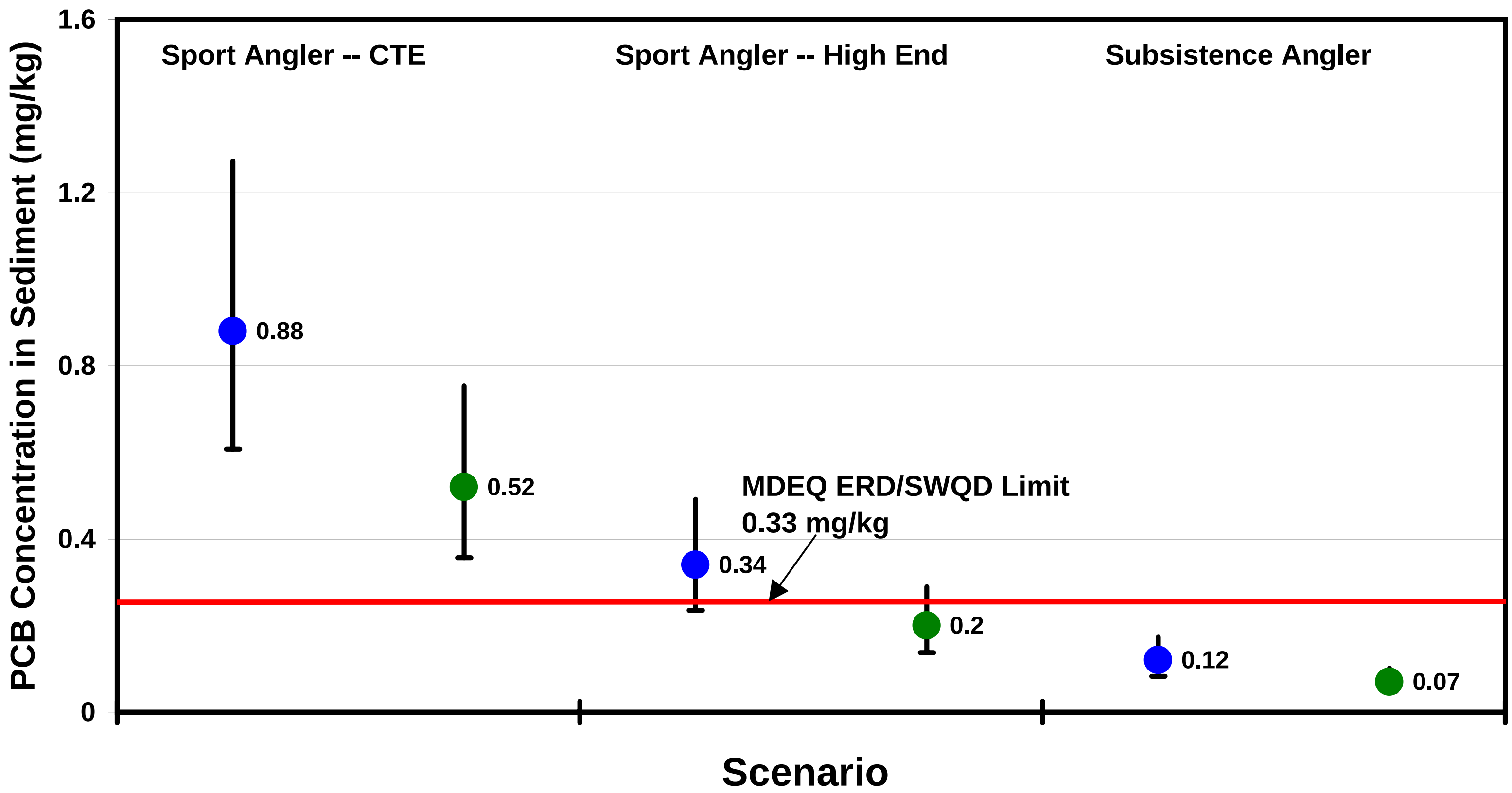


Note: RBC for Bass Only Consumption in Blue; RBC for Bass/Carp Consumption in Green

FIGURE 7-3

API/PC/KR SITE

Confidence Intervals for Risk-Based Concentrations Based on Variability in BSAF
RBC_{sed} Based on Hazard Quotient Target of 1



Note: RBC for Bass Only Consumption in Blue; RBC for Bass/Carp Consumption in Green

FIGURE 7-4

API/PC/KR SITE

Section 8
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Appendix A
Biota-to-Sediment Accumulation Factors and Remedial Action Objectives

Appendix A
Biological Sediment Accumulation Factor and Remedial Action Objective Uncertainty Analysis

Summary

Confidence limits for biological sediment accumulation factors (BSAF) and sediment remedial action objectives (RAO) were estimated using bootstrapping, a computer resampling method. BSAFs and RAOs were calculated for each of seven aquatic biota sampling areas and sitewide. Sitewide sediment RAOs ranged from 0.032 mg/kg for a mixed (76 percent bass, 24 percent carp) diet for subsistence anglers to 0.17 mg/kg for central tendency anglers on a mixed fish fillet diet. BSAFs and RAOs were based on 263 fish fillet samples and 621 surficial (top 2 inches) sediment samples. Upper and lower confidence limits for RAOs tended to differ by approximately a factor of 2, although it is thought that decisions based on either upper or lower confidence limits would result in similar remedial decisions. Note that Section 6 of this risk assessment presents RBC_{sed} values that are not to be confused with the RAOs presented here for discussion. The stochastic analysis presented in this appendix was not used in the calculation of the RBC_{sed} values of Section 6.

Introduction

BSAFs and RAOs were calculated for each of seven aquatic biota study areas (ABSA) at the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site. BSAFs were based on lipid normalized fish fillets and organic carbon normalized sediment concentration, and RAOs were designed to be protective of $1x10^{-5}$ cancer risk for central tendency, high-end sport, and subsistence anglers. Approximately 95% confidence limits were calculated for BSAFs and RAOs.

Because BSAFs and RAOs are ratios of random variables, no formulas are available for their exact sampling variances, so approximately 95% confidence limits were estimated using bootstrap resampling (Efron 1982). Additionally, to check the accuracy of bootstrap estimates, Taylor series approximation (Cochran 1977) was used to estimate confidence limits for the BSAF at Lake Allegan. The bootstrap estimates are nonparametric, while the Taylor approximation requires the assumption that the sampling distribution is approximately normally distributed. Confidence limits for sediment RAOs were estimated for each ABSA separately and for the entire site (i.e., a sitewide RAO) for diets composed of 100 percent carp or smallmouth bass, and a combined diet composed of 76 percent bass and 24 percent carp.

Bootstrap Sampling Method

Bootstrap estimation is a computer intensive resampling method for estimating sampling distributions and confidence limits of statistics for which the theoretical sampling distribution is not known. To estimate 95% confidence limits for the mean of n samples, one would repeatedly (1,000 to 10,000 times) select n records with replacement from the original data and calculate the mean of each bootstrap sample. The 97.5th and 2.5th percentiles of the bootstrap distribution are estimates of the 95% confidence limits.

The bootstrap algorithm described in Figure 1 was implemented in MATLAB© (The Mathworks 1998). To ensure that the random sampling algorithm was unbiased, the number of times each sample record was included in a bootstrap sample was counted and displayed in histograms. To demonstrate the correct algorithm performance, the resulting histogram is included for Lake Allegan (Figure 2). The bootstrap distributions of normalized mean fillet and sediment concentrations are displayed in Figure 3. The bootstrap distribution of the BSAF at Lake Allegan is summarized in a histogram of cumulative distribution plot in Figure 4. Confidence limits for sitewide and ABSA-specific BSAFs and RAOs are summarized in Tables 1 through 7.

Taylor Series Approximation

Define C_f and C_s to be normalized PCB concentration in fish fillets and sediment respectively. The biological sediment accumulation factor is given by:

$$BSAF = \overline{C}_f / \overline{C}_s$$

Defining $Var(\overline{C}_k) = S_k^2 / n_k$ for (k=f,s) to be the variance of each mean, the first order Taylor series approximation to the variance of the BSAF is

$$Var(BSAF) \cong (BSAF)^2 x \left\{ \frac{\mathrm{var}(\overline{C}_f)}{\overline{C}_f^2} + \frac{\mathrm{var}(Cs)}{\overline{C}_s^2} - 2x \frac{Cov(\overline{C}_f, \overline{C}_s)}{\overline{C}_f x \overline{C}_s} \right\}$$

For sufficiently large sample sizes, approximately (1-∀) 100 percent confidence limits are given by:

$$BSAF \pm z_{a/2} \sqrt{Var(BSAF)}$$

Confidence limits for the BSAF at Lake Allegan were approximated using the Taylor approximation for comparison with the bootstrap estimates.

Results

Comparison of Bootstrap and Taylor Estimates at Lake Allegan

The bootstrap algorithm was implemented as in Figure 1. It can be seen in Figure 2 that each record had approximately uniform probability of inclusion in each bootstrap sample. The bootstrap distribution of average normalized fish and sediment concentrations are displayed in Figure 3. The average lipid normalized fish concentrations are symmetrically distributed about a mean of 156 (mg-PCB / kg-lipid), while the distribution of the average normalized sediment concentration is somewhat skewed toward higher values.

The 10,000 bootstrap estimates of the BSAF at ABSA 9 ranged from 0.35 to 2.8 with an average of 0.99 and a median of 0.94. The bootstrap estimated lower and upper 95% confidence limits are 0.55 and 1.68 respectively. The Taylor expansion estimated lower and upper 95% confidence limits are 0.39 and 1.48 respectively. The Taylor expansion confidence limits are similar to the bootstrap confidence limits. This similarity provides an added level of scientific credibility that the bootstrap algorithm is performing properly. It should be noted that the Taylor expansion requires the assumption of a symmetric interval, while the bootstrap distribution is somewhat asymmetric with a longer upper-, than lower-tail. Because fewer assumptions are required to justify it, the bootstrap interval is preferred. Confidence intervals for BSAFs and RAOs for the remaining ABSAs are based on bootstrap estimation.

Bootstrap BSAF and RAO Estimates

Average BSAFs for smallmouth bass ranged from 0.21 at ABSA 6 (Otsego City Dam) to 2.6 at ABSA 8 (Trowbridge Dam; Table 1) while for carp, BSAFs ranged from 0.34 at ABSA 7 (Otsego Dam) to 3.8 at ABSA 8 (Table 2). Sitewide BSAFs are approximated by averaging the BSAFs across ABSAs and reported in the last row of Tables 1 and 2.

Sitewide RAOs were estimated for fish tissue concentrations of 0.042, 0.023, 0.021, and 0.008 mg/kg in smallmouth bass and carp respectively (Tables 3 and 4). Sediment RAOs were also calculated for a mixed diet of 76 percent bass and 24 percent carp. To be protective of central tendency anglers (0.042 mg/kg fish tissue concentration) with a mixed diet, a sediment RAO of 0.17 is estimated with 95% confidence interval of 0.12- to 0.25-mg/kg (Table 5). To be protective of subsistence anglers on a mixed diet, a sediment RAO ranging from 0.021 to 0.048 is estimated (Table 5). ABSA specific upper 95% confidence limits on RAOs for smallmouth bass ranged from 0.15mg/kg at Trowbridge Dam to 3.7 mg/kg at Otsego City Dam; however, all other upper confidence limits were less than 1.0 mg/kg for both carp and bass (Tables 6 and 7).

The sampling variance of BSAFs and RAOs was estimated using bootstrap resampling procedures. In general, upper and lower confidence limits for RAOs differed by a factor of 2; however, all sitewide RAOs for mixed diets were less than 0.25 with 95% confidence. Given the practical limits of remedial technologies, a factor of 2 variability in RAO estimates is adequate precision to make remedial decisions.

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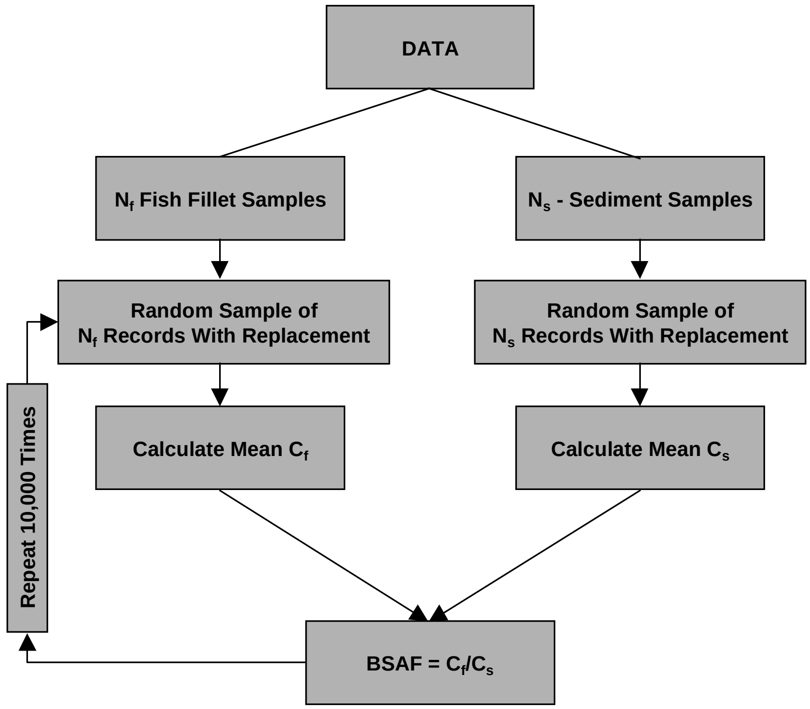

Figure 1 - Bootstrap sampling algorithm for the distribution of BSAF and RAO.

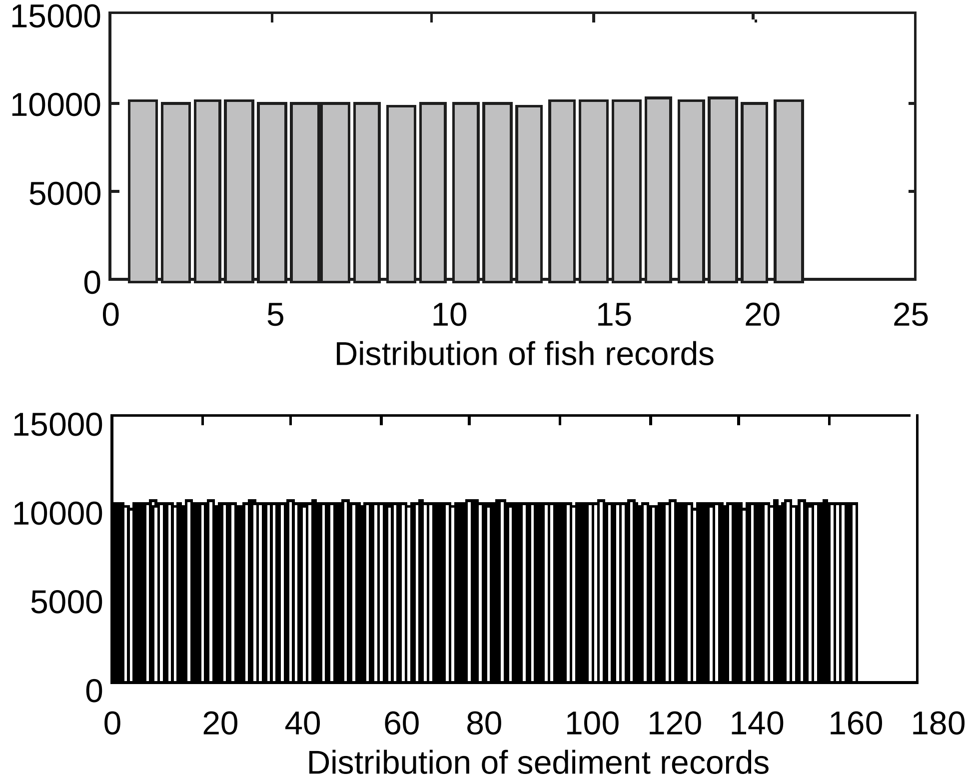

Figure 2 - Frequency of inclusion of each record among 10,000 bootstrap samples. There are 21 fish records and 166 sediment records.

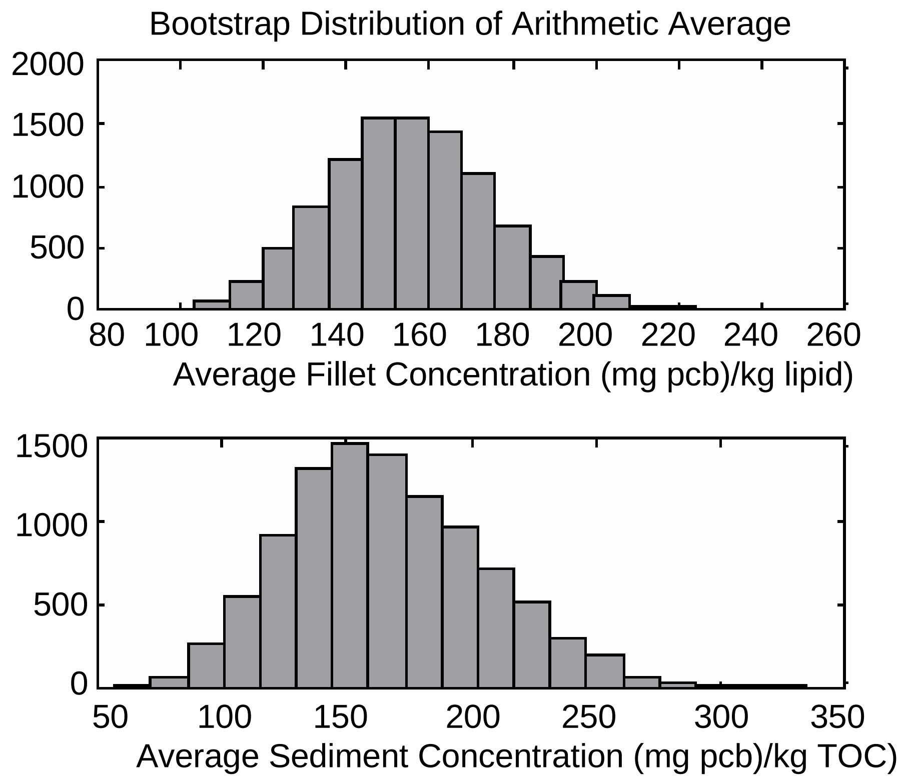

Figure 3 - Bootstrap distributions of arithmetic average normalized fillet and sediment concentrations ABSA 9.

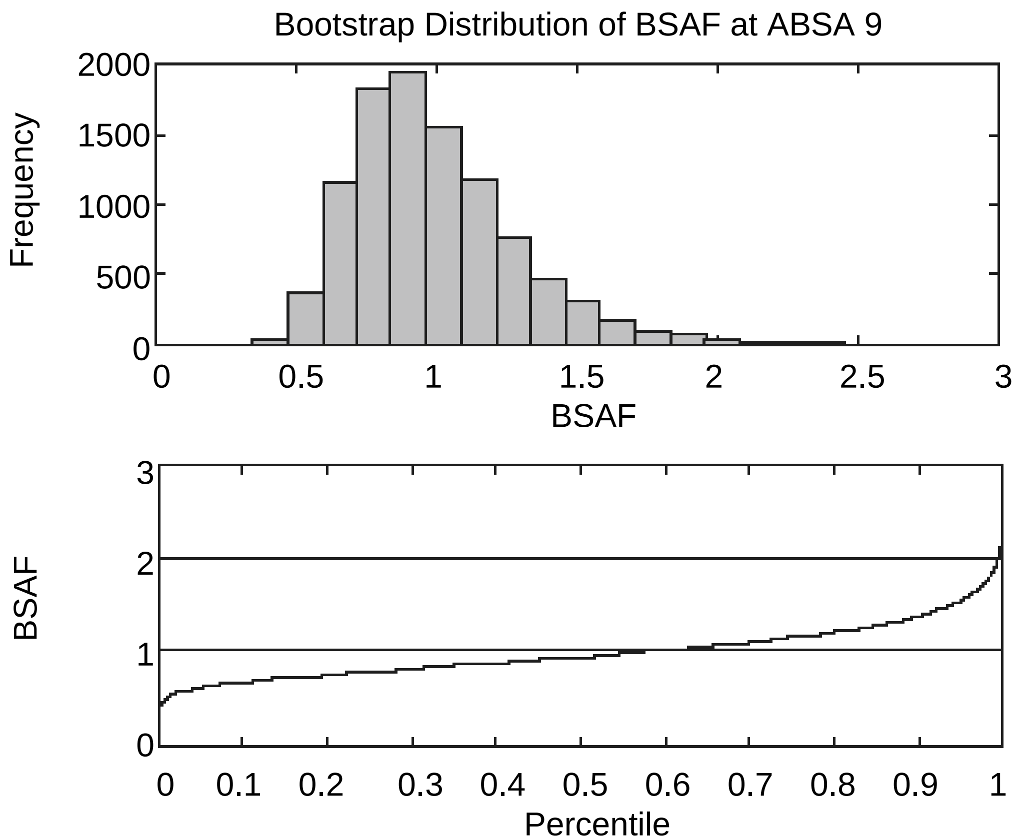

Figure 4 - Bootstrap distribution of BSAF at ABSA 9.

Table 1 Bootstrap Distributions of BSAF for Smallmouth Bass

ABSA	BSAF	Bootstrap BSAF Distribution			
		Mean	Median	LCL95	UCL95
3	0.296	0.314	0.301	0.182	0.515
4	0.604	0.669	0.620	0.343	1.261
5	0.432	0.638	0.443	0.194	1.916
6	0.092	0.208	0.099	0.028	0.891
7	0.371	0.470	0.393	0.183	1.161
8	2.296	2.590	2.373	1.303	5.148
9	0.708	0.755	0.723	0.438	1.249
Sitewide Average		0.806	0.707	0.382	1.735

Table 2 Bootstrap Distributions of BSAF for Common Carp

ABSA	BSAF	Bootstrap BSAF Distribution			
		Mean	Median	LCL95	UCL95
3	0.523	0.557	0.536	0.302	0.939
4	1.113	1.235	1.155	0.636	2.298
5	0.313	0.466	0.332	0.143	1.455
6	0.202	0.463	0.219	0.068	1.954
7	0.275	0.341	0.288	0.124	0.861
8	3.437	3.854	3.506	1.807	7.990
9	0.935	0.991	0.950	0.554	1.677
Sitewide Average		1.130	0.998	0.519	2.453

Table 3 Sitewide PCB Concentrations in Sediment Protective for Selected Levels of Smallmouth Bass Tissue Concentrations

Tissue (mg/kg)		Bootstrap RAO Distribution (mg/kg)			
		Mean	Median	LCL95	UCL95
0.042	0.203	0.205	0.200	0.136	0.300
0.023	0.111	0.112	0.109	0.073	0.163
0.021	0.101	0.102	0.099	0.066	0.150
0.008	0.039	0.039	0.038	0.026	0.058

Table 4 Sitewide PCB Concentrations in Sediment Protective for Selected Levels of Carp Tissue Concentrations

Tissue (mg/kg)		Bootstrap RAO Distribution (mg/kg)			
		Mean	Median	LCL95	UCL95
0.042	0.063	0.064	0.062	0.041	0.093
0.023	0.028	0.028	0.027	0.018	0.043
0.021	0.031	0.032	0.031	0.021	0.046
0.008	0.012	0.012	0.012	0.008	0.018

Table 5 Sitewide PCB Concentrations in Sediment Protective for 76 Percent Smallmouth Bass and 24 Percent Carp Tissue Concentrations

Tissue (mg/kg)	Bootstrap RAO Distribution (mg/kg)			
	Mean	Median	LCL95	UCL95
0.042	0.170	0.166	0.112	0.248
0.023	0.091	0.089	0.059	0.133
0.021	0.084	0.082	0.055	0.124
0.008	0.032	0.031	0.021	0.048

Table 6 PCB Concentrations in Sediment Protective for Selected Levels of Smallmouth Bass Tissue Concentrations

	Tissue (mg/kg)	Data RAO	Bootstrap RAO Distribution (mg/kg)			
			Mean	Median	LCL95	UCL95
3	0.042	0.119	0.122	0.115	0.059	0.225
4	0.042	0.167	0.171	0.163	0.077	0.311
5	0.042	0.416	0.410	0.390	0.096	0.854
6	0.042	1.196	1.289	1.126	0.134	3.724
7	0.042	0.207	0.211	0.188	0.054	0.494
8	0.042	0.075	0.076	0.072	0.032	0.146
9	0.042	0.098	0.099	0.096	0.056	0.161
3	0.021	0.059	0.062	0.058	0.029	0.112
4	0.021	0.084	0.085	0.081	0.040	0.154
5	0.021	0.208	0.207	0.196	0.045	0.425
6	0.021	0.598	0.627	0.551	0.065	1.852
7	0.021	0.103	0.105	0.094	0.029	0.246
8	0.021	0.037	0.038	0.036	0.015	0.072
9	0.021	0.049	0.050	0.048	0.027	0.081
3	0.008	0.023	0.023	0.022	0.011	0.043
4	0.008	0.032	0.033	0.031	0.015	0.058
5	0.008	0.079	0.079	0.075	0.018	0.164
6	0.008	0.228	0.243	0.212	0.024	0.713
7	0.008	0.039	0.040	0.036	0.010	0.097
8	0.008	0.014	0.015	0.014	0.006	0.028
9	0.008	0.019	0.019	0.018	0.010	0.032

Table 7 PCB Concentrations in Sediment Protective for Selected Levels of Common Carp Tissue Concentrations

	Tissue (mg/kg)	Data RAO	Bootstrap RAO Distribution (mg/kg)			
			Mean	**Median**	**LCL95**	**UCL95**
3	0.042	0.024	0.025	0.024	0.013	0.043
4	0.042	0.012	0.012	0.012	0.006	0.023
5	0.042	0.128	0.132	0.124	0.028	0.293
6	0.042	0.298	0.317	0.278	0.035	0.915
7	0.042	0.103	0.109	0.095	0.028	0.263
8	0.042	0.027	0.029	0.027	0.011	0.061
9	0.042	0.189	0.195	0.186	0.100	0.339
3	0.021	0.012	0.012	0.012	0.006	0.022
4	0.021	0.006	0.006	0.006	0.003	0.011
5	0.021	0.064	0.065	0.060	0.014	0.143
6	0.021	0.149	0.161	0.141	0.018	0.474
7	0.021	0.052	0.055	0.049	0.014	0.131
8	0.021	0.013	0.015	0.013	0.005	0.032
9	0.021	0.094	0.098	0.094	0.050	0.169
3	0.008	0.005	0.005	0.004	0.002	0.008
4	0.008	0.002	0.002	0.002	0.001	0.004
5	0.008	0.024	0.025	0.024	0.006	0.055
6	0.008	0.057	0.060	0.053	0.006	0.173
7	0.008	0.020	0.021	0.018	0.005	0.050
8	0.008	0.005	0.006	0.005	0.002	0.012
9	0.008	0.036	0.037	0.035	0.019	0.064

Appendix B
Human Health Risk Assessment
Data and Calculations

Kalamazoo Risk and Hazard Calculation Spreadsheets

Common Term Calculations by Exposure Scenario

Cancer Risks **Scenario**	fillet/meal (kg)	meals/year	Reduction Fa	Fraction Ingest	ED (yr)	BW (kg)	AT (days)	Slope Factor or Reference Dose (mg/kg-d)^-1 or mg/kg/d)	Constant Term
Sport Angler CTE	0.227	24	0.5	1	30	70	25550	2	**9.14E-05**
Sport Angler High End	0.227	125	0.5	0.5	30	70	25550	2	**2.38E-04**
Subsistance Angler	0.227	179	0.5	1	30	70	25550	2	**6.82E-04**
Non-Cancer Hazards (Reproductive Endpoint)									
Scenario									
Sport Angler CTE	0.227	24	0.5	1	2	70	730	0.00007	**1.52**
Sport Angler High End	0.227	125	0.5	0.5	2	70	730	0.00007	**3.97**
Subsistance Angler	0.227	179	0.5	1	2	70	730	0.00007	**11.36**
Non-Cancer Hazards (Immunological Endpoint)									
Scenario									
Sport Angler CTE	0.227	24	0.5	1	30	70	10950	0.00002	**5.33**
Sport Angler High End	0.227	125	0.5	0.5	30	70	10950	0.00002	**13.88**
Subsistance Angler	0.227	179	0.5	1	30	70	10950	0.00002	**39.76**

For risk and hazard calculations, exposure point concentrations were multiplied by the appropriate constant term.

RISK AND HAZARD CALCULATIONS USING MAXIMUM TISSUE CONCENTRATIONS ABSA-BY-ABSA

ABSA-Specific Fish Fillet Data	ABSA	Max fillet concentration	Avg fillet concentration	76/24 Diet (Bass/Carp) Maximum Concentrations	Sport Angler (CTE) Risk Max	Sport Angler (CTE) Repro. Endpoint Hazard Max	Sport Angler (CTE) Immo. Endpoint Hazard Max	Sport Angler High End Risk Max	Sport Angler High End Repro. Endpoint Hazard Max	Sport Angler High End Immo. Endpoint Hazard Max	Subsistence Angler Risk Max	Subsistence Angler Repro. Endpoint Hazard Max	Subsistence Angler Immno. Endpoint Hazard Max
Carp 1	1	1.7E-01	8.3E-02	2.8E-01	2.5E-05	4.2E-01	1.5E+00	6.6E-05	1.1E+00	3.8E+00	1.9E-04	3.1E+00	1.1E+01
Carp 2	2	1.9E+00	6.1E-01	9.7E-01	8.8E-05	1.5E+00	5.1E+00	2.3E-04	3.8E+00	1.3E+01	6.6E-04	1.1E+01	3.8E+01
Carp 3		8.2E+00	6.1E-01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carp 4		1.3E+01	6.6E+00	(ABSA 3,4&5)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carp 5 (EPC is maximum for 3,4&5)	3,4,5	1.7E+01	5.8E+00	7.1E+00	6.5E-04	1.1E+01	3.8E+01	1.7E-03	2.8E+01	9.8E+01	4.8E-03	8.0E+01	2.8E+02
Carp 6	6	8.0E+00	3.4E+00	4.7E+00	4.3E-04	7.2E+00	2.5E+01	1.1E-03	1.9E+01	6.5E+01	3.2E-03	5.3E+01	1.9E+02
Carp 7	7	6.4E+00	2.7E+00	4.4E+00	4.0E-04	6.7E+00	2.3E+01	1.0E-03	1.7E+01	6.1E+01	3.0E-03	5.0E+01	1.7E+02
Carp 8	8	9.6E+00	4.6E+00	5.5E+00	5.0E-04	8.4E+00	2.9E+01	1.3E-03	2.2E+01	7.6E+01	3.7E-03	6.2E+01	2.2E+02
Carp 9	9	6.5E+00	1.8E+00	6.0E+00	5.5E-04	9.1E+00	3.2E+01	1.4E-03	2.4E+01	8.3E+01	4.1E-03	6.8E+01	2.4E+02
Carp 10	10	1.7E+01	7.6E+00	5.9E+00	5.4E-04	9.0E+00	3.2E+01	1.4E-03	2.3E+01	8.2E+01	4.0E-03	6.7E+01	2.4E+02
Carp 11	11	9.1E+00	4.9E+00	2.8E+00	2.6E-04	4.3E+00	1.5E+01	6.7E-04	1.1E+01	3.9E+01	1.9E-03	3.2E+01	1.1E+02
Carp 12	12	8.8E+00	3.4E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Small Mouth Bass 1	1	3.1E-01	1.3E-01	N/A	2.8E-05	4.7E-01	1.6E+00	7.4E-05	1.2E+00	4.3E+00	2.1E-04	3.5E+00	1.2E+01
Small Mouth Bass 2	2	6.7E-01	2.8E-01	N/A	6.1E-05	1.0E+00	3.6E+00	1.6E-04	2.7E+00	9.3E+00	4.6E-04	7.6E+00	2.7E+01
Small Mouth Bass 3		3.2E+00	1.1E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Small Mouth Bass 4		7.2E-01	4.8E-01	(ABSA 3,4&5)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Small Mouth Bass 5 (EPC is maximum for 3,4&5	3,4,5	3.9E+00	1.8E+00	3.9E+00	3.6E-04	5.9E+00	2.1E+01	9.3E-04	1.5E+01	5.4E+01	2.7E-03	4.4E+01	1.5E+02
Small Mouth Bass 6	6	3.7E+00	9.9E-01	N/A	3.3E-04	5.6E+00	2.0E+01	8.7E-04	1.5E+01	5.1E+01	2.5E-03	4.2E+01	1.5E+02
Small Mouth Bass 7	7	3.7E+00	1.5E+00	N/A	3.4E-04	5.7E+00	2.0E+01	8.9E-04	1.5E+01	5.2E+01	2.5E-03	4.2E+01	1.5E+02
Small Mouth Bass 8	8	4.2E+00	1.9E+00	N/A	3.8E-04	6.4E+00	2.2E+01	1.0E-03	1.7E+01	5.8E+01	2.9E-03	4.8E+01	1.7E+02
Small Mouth Bass 9	9	5.8E+00	3.3E+00	N/A	5.3E-04	8.8E+00	3.1E+01	1.4E-03	2.3E+01	8.1E+01	4.0E-03	6.6E+01	2.3E+02
Small Mouth Bass 10	10	2.4E+00	1.9E+00	N/A	2.2E-04	3.7E+00	1.3E+01	5.8E-04	9.6E+00	3.4E+01	1.6E-03	2.7E+01	9.6E+01
Small Mouth Bass 11	11	8.3E-01	5.4E-01	N/A	7.6E-05	1.3E+00	4.4E+00	2.0E-04	3.3E+00	1.2E+01	5.7E-04	9.4E+00	3.3E+01

Risk and hazard calculations were not performed individually for ABSAs 3, 4 & 5. As described in the text, these ABSAs were considered a single biological exposure unit.

RISK AND HAZARD CALCULATIONS USING AVERAGE TISSUE CONCENTRATIONS ABSA-BY-ABSA

ABSA-Specific Fish Fillet Data	ABSA	Max fillet concentration	Avg fillet concentration	76/24 Diet (Bass/Carp) Average Concentrations	Sport Angler (CTE) Risk Avg	Sport Angler (CTE) Repro. Endpoint Hazard Avg	Sport Angler (CTE) Immo. Endpoint Hazard Avg	Sport Angler High End Risk Avg	Sport Angler High End Repro. Endpoint Hazard Avg	Sport Angler High End Immo. Endpoint Hazard Avg	Subsistence Angler Risk Avg	Subsistence Angler Repro. Endpoint Hazard Avg	Subsistence Angler Immno. Endpoint Hazard Avg
Carp 1	1	1.7E-01	8.3E-02	1.2E-01	1.1E-05	1.9E-01	6.5E-01	2.9E-05	4.9E-01	1.7E+00	8.3E-05	1.4E+00	4.9E+00
Carp 2	2	1.9E+00	6.1E-01	3.6E-01	3.3E-05	5.5E-01	1.9E+00	8.6E-05	1.4E+00	5.0E+00	2.5E-04	4.1E+00	1.4E+01
Carp 3		8.2E+00	6.1E-01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carp 4		1.3E+01	6.6E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carp 5 (EPC is average for 3,4&5)	3,4,5	1.7E+01	5.8E+00	1.9E+00	1.7E-04	2.9E+00	1.0E+01	4.5E-04	7.5E+00	2.6E+01	1.3E-03	2.1E+01	7.5E+01
Carp 6	6	8.0E+00	3.4E+00	1.6E+00	1.4E-04	2.4E+00	8.4E+00	3.7E-04	6.2E+00	2.2E+01	1.1E-03	1.8E+01	6.3E+01
Carp 7	7	6.4E+00	2.7E+00	1.8E+00	1.6E-04	2.7E+00	9.4E+00	4.2E-04	7.0E+00	2.5E+01	1.2E-03	2.0E+01	7.0E+01
Carp 8	8	9.6E+00	4.6E+00	2.6E+00	2.4E-04	3.9E+00	1.4E+01	6.1E-04	1.0E+01	3.6E+01	1.8E-03	2.9E+01	1.0E+02
Carp 9	9	6.5E+00	1.8E+00	2.9E+00	2.7E-04	4.5E+00	1.6E+01	7.0E-04	1.2E+01	4.1E+01	2.0E-03	3.3E+01	1.2E+02
Carp 10	10	1.7E+01	7.6E+00	3.3E+00	3.0E-04	5.0E+00	1.7E+01	7.8E-04	1.3E+01	4.5E+01	2.2E-03	3.7E+01	1.3E+02
Carp 11	11	9.1E+00	4.9E+00	1.6E+00	1.5E-04	2.4E+00	8.5E+00	3.8E-04	6.3E+00	2.2E+01	1.1E-03	1.8E+01	6.3E+01
Carp 12	12	8.8E+00	3.4E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Small Mouth Bass 1	1	3.1E-01	1.3E-01	N/A	1.2E-05	2.1E-01	7.2E-01	3.2E-05	5.3E-01	1.9E+00	9.2E-05	1.5E+00	5.4E+00
Small Mouth Bass 2	2	6.7E-01	2.8E-01	N/A	2.6E-05	4.3E-01	1.5E+00	6.7E-05	1.1E+00	3.9E+00	1.9E-04	3.2E+00	1.1E+01
Small Mouth Bass 3		3.2E+00	1.1E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Small Mouth Bass 4		7.2E-01	4.8E-01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Small Mouth Bass 5 (EPC is average for 3,4&5)	3,4,5	3.9E+00	1.8E+00	1.1E+00	1.0E-04	1.7E+00	5.9E+00	2.7E-04	4.4E+00	1.5E+01	7.6E-04	1.3E+01	7.1E+01
Small Mouth Bass 6	6	3.7E+00	9.9E-01	N/A	9.0E-05	1.5E+00	5.3E+00	2.3E-04	3.9E+00	1.4E+01	6.7E-04	1.1E+01	3.9E+01
Small Mouth Bass 7	7	3.7E+00	1.5E+00	N/A	1.4E-04	2.3E+00	7.9E+00	3.5E-04	5.9E+00	2.1E+01	1.0E-03	1.7E+01	5.9E+01
Small Mouth Bass 8	8	4.2E+00	1.9E+00	N/A	1.8E-04	3.0E+00	1.0E+01	4.6E-04	7.7E+00	2.7E+01	1.3E-03	2.2E+01	7.7E+01
Small Mouth Bass 9	9	5.8E+00	3.3E+00	N/A	3.0E-04	5.0E+00	1.8E+01	7.8E-04	1.3E+01	4.6E+01	2.2E-03	3.7E+01	1.3E+02
Small Mouth Bass 10	10	2.4E+00	1.9E+00	N/A	1.7E-04	2.9E+00	1.0E+01	4.5E-04	7.5E+00	2.6E+01	1.3E-03	2.1E+01	7.5E+01
Small Mouth Bass 11	11	8.3E-01	5.4E-01	N/A	4.9E-05	8.2E-01	2.9E+00	1.3E-04	2.1E+00	7.5E+00	3.7E-04	6.1E+00	2.1E+01

Risk and hazard calculations were not performed individually for ABSAs 3, 4 & 5. As described in the text, these ABSAs were considered a single biological exposure unit.

Exposure Point Concentrations in Shaded Boxes

KALAMAZOO RISK ASSESSMENT
CALCULATIONS FOR RESIDENTIAL SCENARIO

Residential Scenario
Constant Term Calculations for Cancer Risk

FC	EF_i	EF_d	EF_{inhal}	IR_{soil}	IR_{air}	DF	AE_i	AE_d	AE_{inhal}	VF	PEF	CSF_o	CSF_{inhal}	CF	AT	**Multiplier**
1	350	245	350	114	7.52	353	1	0.14	1	7.30E-07	6.90E-12	2	0.4	1.00E-06	25550	4.07E-06

Area	Maximum Concentration	Average Concentration	Cancer Risk (Max)	Cancer Risk (Ave)	RBC_{cancer}
Plainwell	85	10.864	3.5E-04	4.4E-05	2.5
Otsego	36	8.396	1.5E-04	3.4E-05	2.5
Trowbridge	81.1	12.308	3.3E-04	5.0E-05	2.5

Constant Term Calculations for Hazard Quotients

FC	EF_i	EF_d	EF_{inhal}	IR_{soil}	IR_{air}	DF	AE_i	AE_d	AE_{inhal}	VF	PEF	RfD_{repro}	RfD_{Immuno}	CF	AT	**Multiplier**	
1	350	245	350	114	7.52	353	1	0.14	1	7.30E-07	6.90E-12	0.00007	0.00002	1.00E-06	10950	6.79E-02	Reproductive Endpoin
1	350	245	350	7.6	0.50	23.5	1	0.14	1	7.30E-07	6.90E-12	0.00007	0.00002	1.00E-06	730	2.37E-01	Immunological Endpoi

Area	Maximum Concentration	Average Concentration	Hazard (Max)	Hazard Average	Hazard (Max)	Hazard Average	RBC_{repro}	RBC_{immuno}
			Reproductive		Immunological			
Plainwell	85	10.864	5.8E+00	7.4E-01	2.0E+01	2.6E+00	15	4
Otsego	36	8.396	2.4E+00	5.7E-01	8.5E+00	2.0E+00	15	4
Trowbridge	81.1	12.308	5.5E+00	8.4E-01	1.9E+01	2.9E+00	15	4

Note: Exposure duration for the immunological endpoint is 2 years. IR_{air}, IR_{soil} and DF for this endpoint are multiplied by 2/30 to correct for this shorter exposure period.

RBCs in Shaded Cells

KALAMAZOO RISK ASSESSMENT
CALCULATIONS FOR RECREATIONAL SCENARIO

Recreational Exposure
Constant Term Calculations for Cancer Risk

FC	EF_i	EF_d	EF_{inhal}	IR_{soil}	IR_{air}	DF	AE_i	AE_d	AE_{inhal}	VF	PEF	CSF_o	CSF_{inhal}	CF	AT	**Multiplier**
1	128	128	128	34.29	1.37	61.73	1	0.14	1	7.30E-07	6.90E-12	2	0.4	1.00E-06	25550	4.30E-07

Area	Maximum Concentration	Average Concentration	Cancer Risk (Max)	Cancer Risk (Ave)	RBC_{cancer}
Plainwell	85	10.864	3.7E-05	4.7E-06	23
Otsego	36	8.396	1.5E-05	3.6E-06	23
Trowbridge	81.1	12.308	3.5E-05	5.3E-06	23

Constant Term Calculations for Hazard Quotients

FC	EF_i	EF_d	EF_{inhal}	IR_{soil}	IR_{air}	DF	AE_i	AE_d	AE_{inhal}	VF	PEF	RfD_{repro}	RfD_{Immuno}	CF	AT	**Multiplier**	
1	128	128	128	34.3	1.4	61.7	1	0.14	1	7.30E-07	6.90E-12	0.00007	0.00002	1.00E-06	10950	7.17E-03	Reproductive Endpoir
1	128	128	128	2.9	0.11	5.1	1	0.14	1	7.30E-07	6.90E-12	0.00007	0.00002	1.00E-06	730	3.14E-02	Immunological Endpoi

Area	Maximum Concentration	Average Concentration	Hazard (Max)	Hazard Average	Hazard (Max)	Hazard Average	RBC_{repro}	RBC_{immuno}
			Reproductive		Immunological			
Plainwell	85	10.864	6.1E-01	7.8E-02	2.7E+00	3.4E-01	139	32
Otsego	36	8.396	2.6E-01	6.0E-02	1.1E+00	2.6E-01	139	32
Trowbridge	81.1	12.308	5.8E-01	8.8E-02	2.5E+00	3.9E-01	139	32

Calculated Terms
Cancer Risk & Reproductive Hazard

Parameter	SA	AhF	IR_{inhal}	ET	IR_o	ED	BW	Value
IR_{soil}					100	24	70	34.29
IR_{air}			1	4		24	70	1.37
DF	2572	0.07				24	70	61.73

Immunological Hazard

Parameter	SA	AhF	IR_{inhal}	ET	IR_o	ED	BW	Value
IR_{soil}					100	2	70	2.86
IR_{air}			1	4		2	70	0.114
DF	2572	0.07				2	70	5.14

RBCs in Shaded Cells

Calculation of Confidence Intervals for RBC_{sed}

Bass Only Consumption

Scenario	Cancer End-point			Non-Cancer End-point (Immunological)		
	LCL	Mean	UCL	LCL	Mean	UCL
Sport Angler - CTE	0.74	0.51	0.35	1.27	0.88	0.61
Sport Angler - High End	0.29	0.2	0.14	0.49	0.34	0.23
Subsistence Angler	0.10	0.07	0.05	0.17	0.12	0.08

Bass/Carp Exposure

Scenario	Cancer End-point			Non-Cancer End-point (Immunological)		
	LCL	Mean	UCL	LCL	Mean	UCL
Sport Angler - CTE	0.43	0.3	0.21	0.75	0.52	0.36
Sport Angler - High End	0.17	0.12	0.08	0.29	0.2	0.14
Subsistence Angler	0.06	0.04	0.03	0.10	0.07	0.05

Sediment and TOC Data Used in Calculation of BSAF

ABSA	PCB	TOCpct	PCBNORM
3	0.025	0.27	9.26
3	0.0255	0.53	4.81
3	0.026	2.97	0.88
3	0.026	0.78	3.33
3	0.026	0.33	7.88
3	0.026	0.18	14.44
3	0.026	0.15	17.33
3	0.026	0.005	520.00
3	0.026	0.005	520.00
3	0.0265	1.71	1.55
3	0.0265	1.38	1.92
3	0.0265	0.92	2.88
3	0.0265	0.62	4.27
3	0.0265	0.56	4.73
3	0.0265	0.0055	481.82
3	0.0265	0.0055	481.82
3	0.0265	0.0055	481.82
3	0.027	4.47	0.60
3	0.027	3.33	0.81
3	0.027	0.94	2.87
3	0.027	0.26	10.38
3	0.027	0.0524	51.53
3	0.027	0.0055	490.91
3	0.027	0.0055	490.91
3	0.027	0.0055	490.91
3	0.0275	1.65	1.67
3	0.0275	1.42	1.94
3	0.0275	1.11	2.48
3	0.0275	0.81	3.40
3	0.0275	0.75	3.67
3	0.0275	0.74	3.72
3	0.0275	0.0055	500.00
3	0.0275	0.0055	500.00
3	0.028	2.66	1.05
3	0.028	0.43	6.51
3	0.028	0.3	9.33
3	0.028	0.0055	509.09
3	0.028	0.0055	509.09
3	0.028	0.0055	509.09
3	0.0285	1.18	2.42
3	0.0285	1.02	2.79
3	0.0285	0.92	3.10
3	0.0285	0.59	4.83
3	0.0285	0.562	5.07
3	0.0285	0.521	5.47
3	0.0285	0.51	5.59
3	0.0285	0.49	5.82
3	0.0285	0.45	6.33

Sediment and TOC Data Used in Calculation of BSAF

3	0.0285	0.38	7.50
3	0.0285	0.15	19.00
3	0.0285	0.09	31.67
3	0.0285	0.006	475.00
3	0.0285	0.00575	495.65
3	0.0285	0.0055	518.18
3	0.029	1.38	2.10
3	0.029	0.92	3.15
3	0.029	0.16	18.13
3	0.029	0.15	19.33
3	0.029	0.006	483.33
3	0.029	0.005	580.00
	0.0295	0.62	4.76
	0.0295	0.16	18.44
3	0.0295	0.006	491.67
3	0.0295	0.0059	500.00
3	0.03	1.73	1.73
3	0.03	0.84	3.57
3	0.03	0.31	9.68
3	0.03	0.14	21.43
3	0.0305	0.69	4.42
3	0.0305	0.15	20.33
3	0.031	0.86	3.60
3	0.031	0.0063	492.06
3	0.0315	1.89	1.67
3	0.0315	0.19	16.58
3	0.0315	0.0065	484.62
3	0.032	2.59	1.24
3	0.0325	0.471	6.90
3	0.033	0.005	660.00
3	0.0335	0.23	14.57
3	0.034	0.98	3.47
3	0.034	0.311	10.93
3	0.034	0.311	10.93
3	0.034	0.311	10.93
3	0.034	0.311	10.93
	0.0345	0.25	13.80
3	0.035	0.0055	636.36
3	0.0355	0.93	3.82
3	0.037	1.99	1.86
3	0.038	0.94	4.04
3	0.038	0.22	17.27
3	0.038	0.00755	503.31
3	0.0385	3.48	1.11
3	0.0425	3.31	1.28
3	0.046	0.79	5.82
3	0.046	0.005	920.00
3	0.049	0.27	18.15
3	0.059	0.05	118.00

Sediment and TOC Data Used in Calculation of BSAF

3	0.059	0.05	118.00
3	0.059	0.05	118.00
3	0.059	0.05	118.00
3	0.061	0.13	46.92
3	0.063	0.56	11.25
3	0.071	0.83	8.55
3	0.073	0.15	48.67
3	0.075	0.62	12.10
3	0.077	3.9	1.97
3	0.086	0.81	10.62
3	0.094	0.006	1566.67
3	0.097	1.87	5.19
	0.097	1.37	7.08
3	0.102	0.00555	1837.84
3	0.103	0.48	21.46
3	0.11	0.76	14.47
3	0.11	0.5	22.00
3	0.116	0.0062	1870.97
3	0.12	0.2	60.00
3	0.124	0.103	120.39
3	0.124	0.00635	1952.76
3	0.163	7.05	2.31
3	0.172	3.81	4.51
3	0.184	0.35	52.57
3	0.205	1.49	13.76
3	0.207	0.3	69.00
3	0.207	0.3	69.00
3	0.207	0.3	69.00
3	0.207	0.3	69.00
3	0.209	0.52	40.19
3	0.209	0.52	40.19
3	0.209	0.52	40.19
3	0.209	0.52	40.19
3	0.223	0.25	89.20
3	0.26	1.71	15.20
3	0.264	1.33	19.85
3	0.276	0.0065	4246.15
3	0.292	0.2	146.00
3	0.315	1.06	29.72
3	0.37	6.11	6.06
3	0.37	6.11	6.06
3	0.37	6.11	6.06
3	0.37	6.11	6.06
3	0.378	0.69	54.78
3	0.39	0.236	165.25
3	0.43	0.27	159.26
3	0.475	0.18	263.89
3	0.53	0.29	182.76
3	0.54	0.006	9000.00

Sediment and TOC Data Used in Calculation of BSAF

3	0.54	0.006	9000.00
3	0.54	0.006	9000.00
3	0.54	0.006	9000.00
3	0.59	2.05	28.78
3	0.59	0.23	256.52
3	0.67	0.14	478.57
3	0.683	0.075	910.67
3	0.832	1.01	82.38
	1.069	2.1	50.90
3	1.19	0.15	793.33
3	1.218	3.12	39.04
3	1.559	1.03	151.36
3	1.62	0.27	600.00
3	2.43	18.6	13.06
3	2.53	1.35	187.41
3	3.7	0.76	486.84
3	6.6	11.4	57.89
3	6.6	11.4	57.89
3	6.6	11.4	57.89
3	6.6	11.4	57.89
3	44	4.17	1055.16
3	86	7.9	1088.61
4	0.0255	5.33	0.48
4	0.026	1.33	1.95
4	0.026	1.16	2.24
4	0.026	0.79	3.29
4	0.0265	0.202	13.12
4	0.0265	0.005	530.00
4	0.027	2.65	1.02
4	0.027	1.31	2.06
4	0.027	0.844	3.20
4	0.027	0.59	4.58
4	0.027	0.39	6.92
4	0.027	0.36	7.50
4	0.027	0.32	8.44
4	0.027	0.14	19.29
4	0.027	0.14	19.29
4	0.027	0.0055	490.91
4	0.0275	0.7	3.93
4	0.0275	0.51	5.39
4	0.0275	0.11	25.00
4	0.028	0.5	5.60
4	0.028	0.45	6.22
4	0.028	0.36	7.78
4	0.028	0.34	8.24
4	0.028	0.324	8.64
4	0.028	0.32	8.75
4	0.0285	0.96	2.97
4	0.029	0.37	7.84

Sediment and TOC Data Used in Calculation of BSAF

4	0.029	0.31	9.35
4	0.029	0.006	483.33
4	0.0295	0.76	3.88
4	0.03	0.806	3.72
4	0.03	0.68	4.41
4	0.03	0.57	5.26
4	0.03	0.23	13.04
4	0.03	0.0961	31.22
4	0.03	0.092	32.61
4	0.03	0.0298	100.67
4	0.0305	0.407	7.49
4	0.0305	0.36	8.47
4	0.031	2.59	1.20
4	0.031	1.57	1.97
	0.031	0.93	3.33
4	0.031	0.29	10.69
4	0.031	0.147	21.09
4	0.0315	0.15	21.00
4	0.032	1.18	2.71
4	0.032	0.299	10.70
4	0.032	0.123	26.02
4	0.0325	1.07	3.04
4	0.0325	0.0065	500.00
4	0.033	0.42	7.86
4	0.034	1.23	2.76
4	0.034	0.14	24.29
4	0.034	0.006	566.67
4	0.035	0.15	23.33
4	0.036	0.18	20.00
4	0.036	0.11	32.73
4	0.037	1.79	2.07
4	0.037	0.22	16.82
4	0.038	0.86	4.42
4	0.038	0.74	5.14
4	0.038	0.18	21.11
4	0.038	0.093	40.86
4	0.039	0.66	5.91
4	0.039	0.41	9.51
4	0.04	0.34	11.76
4	0.041	0.218	18.81
4	0.042	4.86	0.86
4	0.042	0.64	6.56
4	0.042	0.2	21.00
4	0.043	0.94	4.57
4	0.043	0.64	6.72
4	0.046	1.49	3.09
4	0.046	0.65	7.08
4	0.0465	5.96	0.78
4	0.047	0.51	9.22

Sediment and TOC Data Used in Calculation of BSAF

4	0.0475	4.79	0.99
4	0.048	0.988	4.86
4	0.051	0.22	23.18
4	0.056	0.16	35.00
4	0.058	0.13	44.62
4	0.058	0.1	58.00
4	0.064	3.74	1.71
4	0.065	1.26	5.16
4	0.067	0.5	13.40
4	0.072	1.67	4.31
4	0.072	0.683	10.54
4	0.072	0.27	26.67
4	0.079	1.22	6.48
4	0.082	0.56	14.64
4	0.084	0.42	20.00
4	0.085	12.5	0.68
4	0.088	0.281	31.32
4	0.091	1.21	7.52
4	0.091	0.6	15.17
4	0.094	0.25	37.60
4	0.1	1.02	9.80
4	0.11	1.91	5.76
4	0.11	0.77	14.29
4	0.11	0.093	118.28
4	0.12	2.81	4.27
4	0.12	0.085	141.18
4	0.12	0.00615	1951.22
4	0.125	0.52	24.04
4	0.127	0.046	276.09
4	0.128	1.49	8.59
4	0.13	0.1	130.00
4	0.136	1.06	12.83
4	0.15	0.38	39.47
4	0.155	11	1.41
4	0.16	0.12	133.33
4	0.165	0.198	83.33
4	0.17	0.93	18.28
4	0.173	0.221	78.28
4	0.18	0.54	33.33
4	0.181	0.21	86.19
4	0.189	0.7	27.00
4	0.19	0.0055	3454.55
4	0.207	0.28	73.93
4	0.221	0.15	147.33
4	0.222	0.34	65.29
4	0.23	0.6	38.33
4	0.254	0.0061	4163.93
4	0.26	0.91	28.57
	0.268	1.73	15.49

Sediment and TOC Data Used in Calculation of BSAF

4	0.275	7.26	3.79
4	0.4	1.17	34.19
4	0.4	0.95	42.11
4	0.404	1.22	33.11
4	0.488	3.3	14.79
4	0.5	2.46	20.33
4	0.52	6.6	7.88
4	0.52	1.73	30.06
4	0.548	1.42	38.59
4	0.56	0.793	70.62
4	0.563	0.76	74.08
4	0.567	1.1	51.55
4	0.6	0.49	122.45
4	0.614	0.909	67.55
4	0.67	0.92	72.83
4	0.69	3.55	19.44
4	0.71	4.91	14.46
4	0.713	0.82	86.95
4	0.72	2.15	33.49
4	0.727	2.66	27.33
4	0.729	0.89	81.91
4	0.74	10.9	6.79
4	0.741	2.65	27.96
4	0.811	4.41	18.39
4	0.82	4.33	18.94
4	0.84	3.41	24.63
4	1.04	2.81	37.01
4	1.08	18.7	5.78
4	1.1	0.798	137.84
4	1.12	3.26	34.36
4	1.14	0.55	207.27
4	1.18	1.45	81.38
4	1.33	4.16	31.97
4	1.4	0.21	666.67
4	1.431	11.5	12.44
4	1.47	4.94	29.76
4	1.6	6.52	24.54
4	1.92	3.76	51.06
4	2.1	2.03	103.45
4	2.18	4.36	50.00
4	2.24	1.8	124.44
4	2.27	3.78	60.05
4	2.46	1.04	236.54
4	4.11	10	41.10
4	4.18	6.34	65.93
4	4.24	14.8	28.65
4	4.5	1.55	290.32
4	4.7	10.5	44.76
4	5.47	10.9	50.18

Sediment and TOC Data Used in Calculation of BSAF

4	18.5	16.4	112.80
4	68.5	7.7	889.61
5	0.0325	2.12	1.53
5	0.044	3.17	1.39
5	0.051	4.89	1.04
5	0.055	8.15	0.67
5	0.055	8.15	0.67
5	0.055	6.45	0.85
5	0.055	5.24	1.05
5	0.056	3.74	1.50
5	0.065	9.93	0.65
5	0.065	6.29	1.03
5	0.075	0.0055	1363.64
5	0.125	2.94	4.25
5	0.13	2.96	4.39
5	0.17	0.005	3400.00
5	1.04	4.22	24.64
5	1.99	5.96	33.39
5	1.99	5.96	33.39
5	12.2	5.84	208.90
5	16.1	4.54	354.63
5	55	7.68	716.15
5	99.9	10.6	942.45
5	99.9	10.6	942.45
6	0.0285	0.0165	172.73
6	0.029	0.864	3.36
6	0.0325	0.149	21.81
6	0.041	4.62	0.89
6	0.041	0.0797	51.44
6	0.05	3.95	1.27
6	0.065	5.28	1.23
6	0.065	0.102	63.73
6	0.08	0.0823	97.21
6	0.085	3.53	2.41
6	0.088	0.05	176.00
6	0.093	2.98	3.12
6	0.094	6.13	1.53
6	0.099	0.005	1980.00
6	0.13	0.813	15.99
6	0.17	0.0059	2881.36
6	0.208	0.421	49.41
6	0.345	4.61	7.48
6	0.42	6.27	6.70
6	0.452	3.98	11.36
6	0.476	3.11	15.31
6	0.663	1.06	62.55
6	0.85	13.4	6.34
6	0.86	4.78	17.99
6	0.94	0.449	209.35

Sediment and TOC Data Used in Calculation of BSAF

6	1.29	5.75	22.43
6	1.5	7.84	19.13
6	2.19	10.4	21.06
6	3.07	14.1	21.77
6	4.35	0.02	21750.00
6	5.9	12.59	46.86
6	59	10.7	551.40
6	94	7	1342.86
7	0.027	0.622	4.34
7	0.0285	2.28	1.25
7	0.0285	0.55	5.18
7	0.029	0.0272	106.62
7	0.029	0.0058	500.00
7	0.03	0.275	10.91
7	0.0305	0.005	610.00
7	0.035	0.888	3.94
7	0.04	0.005	800.00
7	0.041	0.393	10.43
7	0.042	1.58	2.66
7	0.053	2.12	2.50
7	0.063	0.3695	17.05
7	0.078	0.85	9.18
7	0.084	0.005	1680.00
7	0.086	1.16	7.41
7	0.086	0.005	1720.00
7	0.095	1.92	4.95
7	0.097	2.07	4.69
7	0.11	0.42	26.19
7	0.12	2.99	4.01
7	0.139	0.16	86.88
7	0.165	0.528	31.25
7	0.197	2.28	8.64
7	0.336	0.005	6720.00
7	0.63	0.723	87.14
7	1.05	0.289	363.32
7	1.46	1.67	87.43
7	1.55	9.92	15.63
7	2.44	8.07	30.24
7	2.83	0.484	584.71
7	4.4	1.08	407.41
7	156	8.33	1872.75
8	0.028	2.44	1.15
8	0.028	0.55	5.09
8	0.0285	0.0563	50.62
8	0.0295	0.484	6.10
8	0.03	0.24	12.50
8	0.035	0.62	5.65
8	0.036	0.752	4.79
8	0.039	0.00525	742.86

Sediment and TOC Data Used in Calculation of BSAF

8	0.042	2.71	1.55
8	0.047	6	0.78
8	0.048	2.94	1.63
8	0.055	4.16	1.32
8	0.06	5.4	1.11
8	0.06	4.72	1.27
8	0.07	11.5	0.61
8	0.07	8.23	0.85
8	0.078	0.943	8.27
8	0.089	0.361	24.65
8	0.097	0.513	18.91
8	0.099	0.0909	108.91
8	0.138	0.697	19.80
8	0.14	7.55	1.85
8	0.158	1.29	12.25
8	0.177	0.871	20.32
8	0.187	5	3.74
8	0.24	0.55	43.64
8	0.343	0.18	190.56
8	0.409	0.754	54.24
8	0.46	0.502	91.63
8	0.56	0.84	66.67
8	0.595	0.151	394.04
8	0.75	4.01	18.70
8	0.97	2.77	35.02
8	1.21	1.94	62.37
8	1.416	0.219	646.58
8	2.21	7.68	28.78
8	2.94	6.78	43.36
8	3	10.7	28.04
8	3.2	1.36	235.29
8	3.89	10.1	38.51
8	4.8	16	30.00
8	12.7	5.88	215.99
8	16.3	11.6	140.52
8	91	7.76	1172.68
9	0.0265	0.00535	495.33
9	0.027	1.01	2.67
9	0.0275	2.37	1.16
9	0.028	0.515	5.44
9	0.028	0.00555	504.50
9	0.0285	0.103	27.67
9	0.0285	0.005	570.00
9	0.029	0.504	5.75
9	0.029	0.312	9.29
9	0.029	0.0208	139.42
9	0.0295	1.63	1.81
9	0.0295	0.605	4.88
9	0.0295	0.0059	500.00

Sediment and TOC Data Used in Calculation of BSAF

9	0.03	0.846	3.55
9	0.03	0.846	3.55
9	0.03	0.846	3.55
9	0.03	0.846	3.55
9	0.03	0.38	7.89
9	0.03	0.0558	53.76
9	0.03	0.0061	491.80
9	0.03	0.00605	495.87
9	0.0315	0.00645	488.37
9	0.032	0.79	4.05
9	0.032	0.0065	492.31
9	0.033	2.92	1.13
9	0.033	0.217	15.21
9	0.033	0.00625	528.00
9	0.034	1.61	2.11
9	0.034	0.028	121.43
9	0.0345	0.673	5.13
9	0.037	1.69	2.19
9	0.04	0.02	200.00
9	0.041	0.17	24.12
9	0.042	6.04	0.70
9	0.042	1.35	3.11
9	0.044	0.449	9.80
9	0.048	0.446	10.76
9	0.048	0.013	369.23
9	0.049	4.71	1.04
9	0.051	0.85	6.00
9	0.054	0.892	6.05
9	0.055	1.55	3.55
9	0.055	0.54	10.19
9	0.055	0.0065	846.15
9	0.068	0.24	28.33
9	0.07	0.04	175.00
9	0.071	0.16	44.38
9	0.072	1.36	5.29
9	0.075	0.51	14.71
9	0.079	0.586	13.48
9	0.099	1.54	6.43
9	0.1	0.94	10.64
9	0.12	0.09	133.33
9	0.15	0.098	153.06
9	0.174	0.563	30.91
9	0.174	0.563	30.91
9	0.174	0.563	30.91
9	0.174	0.563	30.91
9	0.178	3.98	4.47
9	0.18	0.0824	218.45
9	0.186	0.807	23.05
9	0.186	0.03	620.00

Sediment and TOC Data Used in Calculation of BSAF

9	0.199	9.58	2.08
9	0.2	0.00695	2877.70
9	0.207	0.0055	3763.64
9	0.216	0.395	54.68
9	0.232	0.803	28.89
9	0.254	0.323	78.64
9	0.275	1.45	18.97
9	0.278	0.0059	4711.86
9	0.278	0.0059	4711.86
9	0.278	0.0059	4711.86
9	0.278	0.0059	4711.86
9	0.292	0.096	304.17
9	0.31	3.59	8.64
9	0.312	1.79	17.43
9	0.317	0.208	152.40
9	0.33	0.63	52.38
9	0.334	0.18	185.56
9	0.354	1.21	29.26
9	0.366	0.733	49.93
9	0.369	0.95	38.84
9	0.38	1.46	26.03
9	0.421	3.72	11.32
9	0.49	1.29	37.98
9	0.55	2.04	26.96
9	0.569	4.57	12.45
9	0.57	3.19	17.87
9	0.62	1.61	38.51
9	0.62	0.268	231.34
9	0.65	2.33	27.90
9	0.71	1.58	44.94
9	0.73	4.16	17.55
9	0.796	0.838	94.99
9	0.81	4.61	17.57
9	0.83	6.14	13.52
9	1.05	2.83	37.10
9	1.22	6.36	19.18
9	1.31	0.66	198.48
9	1.39	13.4	10.37
9	1.43	7.54	18.97
9	1.46	2.69	54.28
9	1.5	1.59	94.34
9	1.5	0.71	211.27
9	1.53	8.36	18.30
9	1.54	15.9	9.69
9	1.55	11.7	13.25
9	1.63	5.65	28.85
9	1.7	10.9	15.60
9	1.71	5.31	32.20
9	1.73	7.83	22.09

Sediment and TOC Data Used in Calculation of BSAF

9	1.73	6.42	26.95
9	1.74	15.3	11.37
9	1.74	8.14	21.38
9	1.804	15.6	11.56
9	1.83	8	22.88
9	1.83	6.18	29.61
9	1.84	8.26	22.28
9	1.86	9.14	20.35
9	1.88	6.43	29.24
9	1.9	23.5	8.09
9	1.91	7.19	26.56
9	1.99	5.49	36.25
9	2.06	8.83	23.33
9	2.09	9.58	21.82
9	2.13	7.21	29.54
9	2.16	8.32	25.96
9	2.22	4.02	55.22
9	2.38	5.45	43.67
9	2.4	8.15	29.45
9	2.41	8.79	27.42
9	2.42	39.8	6.08
9	2.5	10.1	24.75
9	2.5	9.24	27.06
9	2.59	4.99	51.90
9	2.61	14.8	17.64
9	2.65	13.3	19.92
9	2.68	10.2	26.27
9	2.69	13.8	19.49
9	2.69	9.73	27.65
9	2.8	8.29	33.78
9	2.81	5.59	50.27
9	3.01	7.3	41.23
9	3.02	9.85	30.66
9	3.02	5.82	51.89
9	3.07	10.5	29.24
9	3.1	11.7	26.50
9	3.1	6.37	48.67
9	3.13	10.1	30.99
9	3.15	10.6	29.72
9	3.16	9.43	33.51
9	3.28	10.1	32.48
9	3.37	7.49	44.99
9	3.38	6.44	52.48
9	3.6	8.26	43.58
9	3.6	7.13	50.49
9	3.7	0.84	440.48
9	3.71	5.81	63.86
9	3.72	1.07	347.66
9	3.9	7.65	50.98

Sediment and TOC Data Used in Calculation of BSAF

9	3.95	8.04	49.13
9	4.56	4.76	95.80
9	4.6	5.86	78.50
9	4.9	10.65	46.01
9	5.3	16.9	31.36
9	5.5	2.48	221.77
9	5.6	31.8	17.61
9	6.5	1.99	326.63
9	7	9.45	74.07
9	7.2	9.82	73.32
9	9.4	6.12	153.59
9	15	7.39	202.98
9	41.3	6.31	654.52
9	49	6.74	727.00
9	73	8.34	875.30
10	0.0265	0.23	11.52
10	0.027	0.042	64.29
10	0.036	0.86	4.19

Data for Fish Fillet and Lipid Used in Risk/Hazard Calculation and Estimates for BSAF

SPECIES	ABSA	PCB	FAT	PCBNORM
CARP	1	0.055	1.08	5.09
CARP	1	0.055	0.81	6.79
CARP	1	0.055	0.77	7.14
CARP	1	0.057	1.44	3.96
CARP	1	0.058	0.46	12.61
CARP		0.083	1.44	5.76
CARP	1	0.09	1.21	7.44
CARP	1	0.09	0.35	25.71
CARP	1	0.101	1.3	7.77
CARP	1	0.102	1.42	7.18
CARP	1	0.169	3.19	5.30
CARP	2	0.083	0.16	51.88
CARP	2	0.168	0.22	76.36
CARP	2	0.3	0.69	43.48
CARP	2	0.34	1.07	31.78
CARP	2	0.35	0.67	52.24
CARP	2	0.42	0.95	44.21
CARP	2	0.45	0.4	112.50
CARP	2	0.63	0.86	73.26
CARP	2	1	1.31	76.34
CARP	2	1.12	1.05	106.67
CARP	2	1.9	4.24	44.81
CARP	3	1.4	0.89	157.30
CARP	3	2.72	1.85	147.03
CARP	3	3.04	3.49	87.11
CARP	3	3.25	7.4	43.92
CARP	3	3.4	6.82	49.85
CARP	3	3.51	3.6	97.50
CARP	3	4.1	1.89	216.93
CARP	3	4.26	1.73	246.24
CARP	3	7.3	4.75	153.68
CARP	3	7.5	3.31	226.59
CARP	3	8.2	3.26	251.53
CARP	4	1.17	0.74	158.11
CARP	4	2.59	4.32	59.95
CARP	4	4.09	2.22	184.23
CARP	4	4.98	3.76	132.45
CARP	4	5.21	2.84	183.45
CARP	4	7.2	5.07	142.01
CARP	4	7.23	7.73	93.53
CARP	4	7.3	8.56	85.28
CARP	4	8.35	8.88	94.03
CARP	4	11.36	9.1	124.84
CARP	4	12.6	13.83	91.11
CARP	5	1.44	1.42	101.41
CARP	5	2.14	2.6	82.31
CARP	5	2.26	2.21	102.26
CARP	5	3	3.95	75.95

Data for Fish Fillet and Lipid Used in Risk/Hazard Calculation and Estimates for BSAF

CARP	5	4.9	4.09	119.80
CARP	5	5.7	5.9	96.61
CARP	5	6	2.86	209.79
CARP	5	6.7	12.03	55.69
CARP	5	6.7	3.84	174.48
CARP	5	7.9	7.04	112.22
CARP	5	17.2	11.53	149.18
CARP	6	1.05	1.18	88.98
CARP	6	1.15	0.81	141.98
CARP	6	1.41	0.89	158.43
CARP	6	1.44	7.67	18.77
CARP	6	1.89	4.91	38.49
CARP	6	2.98	0.95	313.68
CARP	6	3.5	1.86	188.17
CARP	6	4.16	1.33	312.78
CARP	6	4.97	1.57	316.56
CARP	6	7.3	7.83	93.23
CARP	6	8.03	2.5	321.20
CARP	7	0.56	0.94	59.57
CARP	7	0.71	3.88	18.30
CARP	7	0.99	0.8	123.75
CARP	7	1.15	0.9	127.78
CARP	7	1.93	1.78	108.43
CARP	7	2.6	2.51	103.59
CARP	7	2.84	1.06	267.92
CARP	7	3.14	2.01	156.22
CARP	7	3.9	2.76	141.30
CARP	7	5.4	2.16	250.00
CARP	7	6.4	6.84	93.57
CARP	8	1.31	0.51	256.86
CARP	8	2.13	0.66	322.73
CARP	8	2.31	1.32	175.00
CARP	8	2.46	2.24	109.82
CARP	8	2.61	0.97	269.07
CARP	8	4.16	0.6	693.33
CARP	8	4.18	0.86	486.05
CARP	8	5.7	1.05	542.86
CARP	8	6.5	1.04	625.00
CARP	8	9.1	3.07	296.42
CARP	8	9.6	5.65	169.91
CARP	9	0.099	0.38	26.05
CARP	9	0.569	0.5	113.80
CARP	9	0.686	0.83	82.65
CARP	9	0.705	0.75	94.00
CARP	9	0.79	0.9	87.78
CARP	9	0.983	1.11	88.56
CARP	9	1.018	2.03	50.15
CARP	9	1.03	0.65	158.46
CARP	9	1.07	0.82	130.49

Data for Fish Fillet and Lipid Used in Risk/Hazard Calculation and Estimates for BSAF

CARP	9	1.08	0.53	203.77
CARP	9	1.12	1.25	89.60
CARP	9	1.16	0.55	210.91
CARP	9	1.24	2.76	44.93
CARP	9	1.33	0.95	140.00
CARP	9	1.55	0.9	172.22
CARP	9	1.93	1	193.00
CARP	9	2.35	1.03	228.16
CARP	9	2.5	1.6	156.25
CARP	9	3.64	0.9	404.44
CARP	9	6.5	2.79	232.97
CARP	9	6.5	1.8	361.11
CARP	10	1.93	1	193.00
CARP	10	2.05	20.2	10.15
CARP	10	2.79	24.8	11.25
CARP	10	4.08	2.56	159.38
CARP	10	4.36	2.6	167.69
CARP	10	6.4	2.07	309.18
CARP	10	7.93	4.52	175.44
CARP	10	10.5	18.8	55.85
CARP	10	12.2	30.7	39.74
CARP	10	14.4	4.05	355.56
CARP	10	17	2.87	592.33
CARP	11	1.39	17.9	7.77
CARP	11	2.16	10.1	21.39
CARP	11	2.58	2.37	108.86
CARP	11	2.89	22.2	13.02
CARP	11	3	3.95	75.95
CARP	11	3.5	6.75	51.85
CARP	11	3.72	4.23	87.94
CARP	11	8.5	4.9	173.47
CARP	11	8.7	6.96	125.00
CARP	11	8.88	2.66	333.83
CARP	11	9.1	7.5	121.33
CARP	12	1.52	1.3	116.92
CARP	12	1.59	0.75	212.00
CARP	12	1.99	2.24	88.84
CARP	12	2	1.07	186.92
CARP	12	2.13	1.51	141.06
CARP	12	3.06	1.26	242.86
CARP	12	3.14	1.65	190.30
CARP	12	4.31	1.41	305.67
CARP	12	4.4	2.31	190.48
CARP	12	4.69	1.62	289.51
CARP	12	8.79	1.44	610.42
SMAL	1	0.049	1.02	4.80
SMAL	1	0.064	0.82	7.80
SMAL	1	0.084	0.9	9.33
SMAL	1	0.093	1.48	6.28

Data for Fish Fillet and Lipid Used in Risk/Hazard Calculation and Estimates for BSAF

SMAL	1	0.098	0.96	10.21
SMAL	1	0.106	1.46	7.26
SMAL	1	0.131	1.06	12.36
SMAL	1	0.138	1.99	6.93
SMAL	1	0.147	1.26	11.67
SMAL	1	0.262	2.27	11.54
SMAL	1	0.309	2.33	13.26
SMAL	2	0.1	0.49	20.41
SMAL	2	0.123	0.67	18.36
SMAL	2	0.139	0.55	25.27
SMAL	2	0.153	1.52	10.07
SMAL	2	0.239	0.58	41.21
SMAL	2	0.244	0.62	39.35
SMAL	2	0.246	0.47	52.34
SMAL	2	0.267	0.44	60.68
SMAL	2	0.352	0.79	44.56
SMAL	2	0.557	1.41	39.50
SMAL	2	0.67	1.9	35.26
SMAL	3	0.384	0.52	73.85
SMAL	3	0.416	1.04	40.00
SMAL	3	0.608	0.97	62.68
SMAL	3	0.749	0.9	83.22
SMAL	3	0.75	0.56	133.93
SMAL	3	0.82	0.67	122.39
SMAL	3	0.89	1.13	78.76
SMAL	3	0.99	1.36	72.79
SMAL	3	1.39	1.49	93.29
SMAL	3	1.71	2.68	63.81
SMAL	3	3.23	2.62	123.28
SMAL	4	0.163	0.44	37.05
SMAL	4	0.283	0.43	65.81
SMAL	4	0.318	0.66	48.18
SMAL	4	0.438	0.62	70.65
SMAL	4	0.44	0.32	137.50
SMAL	4	0.55	0.66	83.33
SMAL	4	0.56	1.49	37.58
SMAL	4	0.574	0.78	73.59
SMAL	4	0.623	0.91	68.46
SMAL	4	0.625	1.34	46.64
SMAL	4	0.72	1.14	63.16
SMAL	5	0.678	0.81	83.70
SMAL	5	1.32	0.61	216.39
SMAL	5	1.352	1	135.20
SMAL	5	1.44	0.85	169.41
SMAL	5	1.48	0.8	185.00
SMAL	5	1.58	1.04	151.92
SMAL	5	1.66	2.36	70.34
SMAL	5	1.74	1.39	125.18
SMAL	5	2.2	1.38	159.42

Data for Fish Fillet and Lipid Used in Risk/Hazard Calculation and Estimates for BSAF

SMAL	5	2.26	1.03	219.42
SMAL	5	3.89	1.55	250.97
SMAL	6	0.274	3.73	7.35
SMAL	6	0.319	1.42	22.46
SMAL	6	0.359	0.81	44.32
SMAL	6	0.59	0.84	70.24
SMAL	6	0.63	0.85	74.12
SMAL	6	0.74	3.08	24.03
SMAL	6	0.9	0.51	176.47
SMAL	6	1.04	1	104.00
SMAL	6	1.05	1.66	63.25
SMAL	6	1.28	1.8	71.11
SMAL	6	3.66	1.44	254.17
SMAL	7	0.39	0.26	150.00
SMAL	7	0.535	0.51	104.90
SMAL	7	0.721	0.5	144.20
SMAL	7	1.07	0.74	144.59
SMAL	7	1.203	0.56	214.82
SMAL	7	1.42	1.42	100.00
SMAL	7	1.68	0.69	243.48
SMAL	7	1.68	0.5	336.00
SMAL	7	1.85	1.34	138.06
SMAL	7	1.98	1.05	188.57
SMAL	7	3.73	1.92	194.27
SMAL	8	0.74	0.34	217.65
SMAL	8	1.159	0.61	190.00
SMAL	8	1.51	0.96	157.29
SMAL	8	1.51	0.78	193.59
SMAL	8	1.55	0.36	430.56
SMAL	8	1.58	0.52	303.85
SMAL	8	1.77	0.58	305.17
SMAL	8	2.17	1.19	182.35
SMAL	8	2.51	1.11	226.13
SMAL	8	2.75	1.59	172.96
SMAL	8	4.19	1.63	257.06
SMAL	9	1.58	1.23	128.46
SMAL	9	1.76	1.85	95.14
SMAL	9	2.14	2.37	90.30
SMAL	9	2.18	2.23	97.76
SMAL	9	3	3.72	80.65
SMAL	9	3.2	2.33	137.34
SMAL	9	3.4	4.06	83.74
SMAL	9	3.4	1.66	204.82
SMAL	9	4.05	4.71	85.99
SMAL	9	5.7	3.65	156.16
SMAL	9	5.8	4.26	136.15
SMAL	10	1.05	0.87	120.69
SMAL	10	1.47	2.68	54.85
SMAL	10	1.56	0.93	167.74

Data for Fish Fillet and Lipid Used in Risk/Hazard Calculation and Estimates for BSAF

SMAL	10	1.699	1.19	142.77
SMAL	10	1.72	1.69	101.78
SMAL	10	1.95	1.71	114.04
SMAL	10	2.11	2	105.50
SMAL	10	2.2	2.65	83.02
SMAL	10	2.23	1.59	140.25
SMAL	10	2.4	2.2	109.09
SMAL	10	2.42	1.93	125.39
SMAL	11	0.13	0.73	17.81
SMAL	11	0.311	0.66	47.12
SMAL	11	0.44	0.8	55.00
SMAL	11	0.47	0.69	68.12
SMAL	11	0.478	1.37	34.89
SMAL	11	0.48	0.52	92.31
SMAL	11	0.576	1.06	54.34
SMAL	11	0.59	0.94	62.77
SMAL	11	0.79	0.73	108.22
SMAL	11	0.81	1.11	72.97
SMAL	11	0.83	0.92	90.22

Appendix C
U.S. Fish and Wildlife Data

TABLE 8. PCB LEVELS IN WATERFOWL COLLECTED FROM THE KALAMAZOO RIVER, AUGUST, 1985

LOCATION	SPECIES	MATURITY	PCB AS 1260 (MG/KG)
MORROW POND	MERGANSER	ADULT	28.00
OTSEGO CITY IMPOUNDMENT	MALLARD	ADULT	4.80
	MALLARD	IMMATURE	2.00
	BLUEWINGED TEAL	IMMATURE	<0.25
TROWBRIDGE IMPOUNDMENT	MALLARD	IMMATURE	1.90
	MALLARD	IMMATURE	0.73
ALLEGAN STATE GAME AREA	WOOD DUCK	IMMATURE	1.50
	CANADA GOOSE	IMMATURE	<0.25
SAUGATUCK	MALLARD	IMMATURE	0.78
	MALLARD	IMMATURE	<0.25
	MALLARD	IMMATURE	<0.25
	MALLARD	IMMATURE	0.60
	MALLARD	IMMATURE	1.70
	MALLARD	IMMATURE	0.55
	MALLARD	IMMATURE	1.90
	MALLARD	IMMATURE	1.04
	MALLARD	ADULT	0.98
	WOOD DUCK	ADULT	<0.25

DRAFT

Based on these results, the entire Saugatuck carp data base for the years 1981, 1983, 1985 and 1986 and the Saugatuck bass data base for the years 1981 and 1985 was analyzed using the Kruskal-Wallis non-parametric test. This analysis again found that no significant ($p = 0.05$) difference between years at this location for either species.

This indicates that there was no change in PCB concentrations in fish at Saugatuck during the 1981-86 time period.

4.2.5 Waterfowl

Waterfowl have been sampled in the Area of Concern in 1985 and 1986 by the United States Fish and Wildlife Service. In 1985, eight immature mallards, one adult mallard and one adult wood duck were analyzed for PCB. The birds were plucked, eviscerated and feet removed prior to analyses. PCB concentrations ranged from 0.25 to 1.9 mg/kg (Table 8). Converting these values to a fat basis, PCB values ranged from 2.7 to 700 ppm. All of the immature ducks collected exceeded the FDA action level of 3 ppm PCB on a fat basis.

In 1986, mute swan eggs were collected as part of the effort to reintroduce the trumpeter swan. The eggs were from the Allegan State Game Area in the vicinity of the Kalamazoo River. Fourteen eggs were anlyzed for PCBs. Concentrations ranged from 0.1 to 1.6 mg/kg with a mean concentration of 0.4 mg/kg (Table 9). This mean concentration is greater than the FDA action level for eggs (0.3 mg/kg).

From: Kalamazoo River Remedial Action Plan
MDNR, 1987

...log No.:
Study I.D. No.: 89-3-002

TITLE: MICHIGAN WATERFOWL CONTAMINANTS SURVEY 57

...yze all samples for the compounds specified under analyses requested.
...rs in parenthesis refer to Michigan DNR Wildlife Region

Sample NO	Common name	Matrix	Sample Type	Sample Location	Sample Wt. (g)	Analyses Requested
WPL-1A	Mallard	Breast/skin	Individual	Kalamazoo River(8)	120.77	OCs, Hg
WPL-1B	Mallard	Breast	Individual	Kalamazoo River	98.95	OCs, Hg
WPL-4A	Mallard	Breast/skin	Individual	Potawatomie Marsh	111.75	OCs, Hg
WPL-4B	Mallard	Breast	Individual	Potawatomie Marsh	89.27	OCs, Hg
WPL-5A	Mallard	Breast	Individual	Potawatomie Marsh	66.45	OCs, Hg
WPL-5B	Mallard	Breast	Individual	Potawatomie Marsh	63.32	OCs, Hg
WPL-6A	Mallard	Breast/skin	Individual	Potawatomie Marsh	68.62	OCs, Hg
WPL-6B	Mallard	Breast	Individual	Potawatomie Marsh	75.29	OCs, Hg
WPL-7A	Mallard	Breast/skin	Individual	Potawatomie Marsh	66.32	OCs, Hg
WPL-8A	Mallard	Breast/skin	Individual	Potawatomie Marsh	90.92	OCs, Hg
WPL-8B	Mallard	Breast	Individual	Potawatomie Marsh	92.56	OCs, Hg
WPL-16A	Mallard	Breast/skin	Individual	Maple River(7)	83.31	OCs, Hg
WPL-16B	Mallard	Breast	Individual	Maple River	64.82	OCs, Hg
WPL-17A	Mallard	Breast/skin	Individual	Maple River	76.61	OCs, Hg
WPL-17B	Mallard	Breast	Individual	Maple River	72.01	OCs, Hg
WPL-23A	Mallard	Breast/skin	Individual	Shiawassee River	105.80	OCs, Hg
WPL-23B	Mallard	Breast	Individual	Shiawassee River	73.00	OCs, Hg
WPL-24A	Mallard	Breast/skin	Individual	Shiawassee River	78.93	OCs, Hg
WPL-24B	Mallard	Breast	Individual	Shiawassee River	70.82	OCs, Hg
WPL-25A	Mallard	Breast/skin	Individual	Shiawassee River	68.14	OCs, Hg
WPL-25B	Mallard	Breast	Individual	Shiawassee River	66.20	OCs, Hg
[illegible]27A	Mallard	Breast/skin	Individual	Shiawassee River	91.48	OCs, Hg
[illegible]7A	Mallard	Breast/skin	Individual	Saginaw Bay (1) (Nayanquin Pt)	68.35	OCs, Hg
WPL-48A	Mallard	Breast/skin	Individual	Nayanquin Pt	47.79	OCs, Hg
WPL-49A	Mallard	Breast/skin	Individual	Nayanquin Pt	111.60	OCs, Hg
WPL-49B	Mallard	Breast	Individual	Nayanquin Pt	73.60	OCs, Hg
WPL-50A	Mallard	Breast/skin	Individual	Nayanquin Pt	91.43	OCs, Hg
WPL-50B	Mallard	Breast	Individual	Nayanquin Pt	72.45	OCs, Hg
WPL-56A	Mallard	Breast/skin	Individual	(Fish Pt.)	61.41	OCs, Hg
WPL-57A	Mallard	Breast/skin	Individual	(Wild Fowl Bay)	88.41	OCs, Hg
WPL-57B	Mallard	Breast	Individual	Wild Fowl Bay	93.25	OCs, Hg
WPL-58A	Mallard	Breast/skin	Individual	(Fish Pt.)	82.17	OCs, Hg
WPL-59A	Mallard	Breast/skin	Individual	Fish Pt.	66.40	Ocs, Hg
WPL-59B	Mallard	Breast	Individual	Fish Pt.	63.07	OCs, Hg
WPL-60A	Mallard	Breast/skin	Individual	Fish Pt.	78.06	OCs, Hg
WPL-60B	Mallard	Breast	Individual	Fish Pt.	72.35	OCs, Hg
WPL-67A	Mallard	Breast	Individual	Reedsburg Flood(11)	70.88	OCs, Hg
WPL-69A	Mallard	Breast	Individual	Mud Lake	74.72	OCs, Hg
WPL-70A	Mallard	Breast	Individual	Houghton Lake	81.01	OCs, Hg
WPL-126A	Mallard	Breast/skin	Individual	Harsens Is. (3)	135.05	OCs, Hg
WPL-127A	Mallard	Breast/skin	Individual	Harsens Is.	108.18	OCs, Hg
WPL-128A	Mallard	Breast/skin	Individual	Harsens Is.	109.31	OCs, Hg
WPL-129A	Mallard	Breast/skin	Individual	Harsens Is.	98.31	OCs, Hg
WPL-130A	Mallard	Breast/skin	Individual	Harsens Is.	81.51	OCs, Hg
WPL-131A	Mallard	Breast/skin	Individual	Harsens Is.	118.47	OCs, Hg
[illegible]-132A	Mallard	Breast/skin	Individual	Harsens Is.	89.66	OCs, Hg
[illegible]132B	Mallard	Breast	Individual	Harsens Is.	100.06	OCs, Hg
[illegible]-133A	Mallard	Breast/skin	Individual	Harsens Is.	115.43	OCs, Hg
WPL-133B	Mallard	Breast	Individual	Harsens Is.	96.47	OCs, Hg
WPL-134A	Mallard	Breast/skin	Individual	Harsens Is.	82.87	OCs, Hg
WPL-134B	Mallard	Breast	Individual	Harsens Is.	92.51	OCs, Hg
WPL-135A	Mallard	Breast/skin	Individual	Harsens Is.	121.02	OCs, Hg
WPL-135B	Mallard	Breast	Individual	Harsens Is.	99.96	OCs, Hg

.E TYPE: Malla.
.st/skin
/ NO 5851
CH NO. 89-3-002
ER NO. 85800-89-08008

MISSISSIPPI STATE CHEMICAL LABORATORY
BOX CR
MISSISSIPPI STATE, MS 39762
REPORT FORM
USDI/FWS

ORGANOCHLORINES

DATE RECEIVED 01/12/90

PARTS PER MILLION AS RECEIVED (WET WT)

FWS #	WPL-1A	WPL-1B	WPL-4A	WPL-4B	WPL-5A	WPL-5B	WPL-6A
LAB #	784228	784229	784230	784231	784232	784233	784234
MATRIX	Mallard Bre./skin	Mallard Breast	Mallard Bre./skin	Mallard Breast	Mallard Breast	Mallard Breast	Mallard Bre./Skin
COMPOUND							
HCB	ND*	ND	ND	ND	ND	ND	ND
α-BHC	ND	ND	ND	ND	ND	ND	ND
γ-BHC	ND	ND	ND	ND	ND	ND	ND
β-BHC	ND	ND	ND	ND	ND	ND	ND
δ-BHC	ND	ND	ND	ND	ND	ND	ND
Oxychlordane	ND	ND	ND	ND	ND	ND	ND
Hept. Epox.	ND	ND	ND	ND	ND	ND	ND
γ-Chlordane	ND	ND	ND	ND	ND	ND	ND
t-Nonachlor	ND	ND	ND	ND	ND	ND	ND
Toxaphene	ND	ND	ND	ND	ND	ND	ND
PCB's (total)	0.29	ND	ND	ND	ND	ND	ND
o, p'-DDE	ND	ND	ND	ND	ND	ND	ND
α-Chlordane	ND	ND	ND	ND	ND	ND	ND
p, p'-DDE	0.01	ND	0.07	0.01	ND	ND	0.01
Dieldrin	ND	ND	ND	ND	ND	ND	ND
o, p'-DDD	ND	ND	ND	ND	ND	ND	ND
Endrin	ND	ND	ND	ND	ND	ND	ND
cis-nonachlor	ND	ND	ND	ND	ND	ND	ND
o, p'-DDT	ND	ND	ND	ND	ND	ND	ND
p, p'-DDD	ND	ND	ND	ND	ND	ND	ND
p, p'-DDT	ND	ND	ND	ND	ND	ND	ND
Mirex	ND	ND	ND	ND	ND	ND	ND
OTHER:							
WEIGHT (g)	120	97.2	111	86.8	65.8	59.3	68.5
MOISTURE (%)	72.5	73.5	69.0	73.0	67.0	71.5	67.5
LIPID (%)	3.75	1.75	8.60	2.35	6.45	2.25	8.60

Lower Level of Detection - 0.01 ppm for Tissue, Soil, Etc 0.05 for Toxaphene and PCBs
For Water, LLD- 0.005 ppm for OCs, Tox , PCBs
**Spike - ppm for
* - Confirmed by GC/Mass Spectrometry
*ND - None Detected
***NS - Not Spiked

Signature

TYPE: Mallard
./skin

NO. 5851
CH NO. 89-3-002
ER NO. 85800-89-08008

MISSISSIPPI STATE CHEMICAL LABORATORY
BOX CR
MISSISSIPPI STATE, MS 39762
REPORT FORM
USDI/FWS

ORGANOCHLORINES

DATE RECEIVED 01/12/90

PARTS PER MILLION AS RECEIVED (WET WT)

FWS #	WPL-6B	WPL-7A	WPL-8A	WPL-8B	WPL-8B	WPL-16A	WPL-16B
LAB #	784235	784236	784237	784238A	784238B	784239	784240
MATRIX	Mallard Breast	Mallard Bre./skin	Mallard Bre./skin	Mallard Breast	Duplicate Ma.Breast	Mallard Bre./skin	Mallard Breast
COMPOUND							
HCB	ND*	ND	ND	ND	ND	ND	ND
α-BHC	ND	ND	ND	ND	ND	ND	ND
r-BHC	ND	ND	ND	ND	ND	ND	ND
β-BHC	ND	ND	ND	ND	ND	ND	ND
δ-BHC	ND	ND	ND	ND	ND	ND	ND
Oxychlordane	ND	ND	ND	ND	ND	ND	ND
Hept. Epox.	ND	ND	ND	ND	ND	ND	ND
r-Chlordane	ND	ND	ND	ND	ND	ND	ND
t-Nonachlor	ND	ND	ND	ND	ND	ND	ND
Toxaphene	ND	ND	ND	ND	ND	ND	ND
PCB's (total)	ND	ND	ND	ND	ND	ND	ND
o, p'-DDE	ND	ND	ND	ND	ND	ND	ND
α-Chlordane	ND	ND	ND	ND	ND	ND	ND
p, p'-DDE	ND	ND	0.01	ND	ND	0.01	ND
Dieldrin	ND	ND	ND	ND	ND	ND	ND
o, p'-DDD	ND	ND	ND	ND	ND	ND	ND
Endrin	ND	ND	ND	ND	ND	ND	ND
cis-nonachlor	ND	ND	ND	ND	ND	ND	ND
o, p'-DDT	ND	ND	ND	ND	ND	ND	ND
p, p'-DDD	ND	ND	ND	ND	ND	ND	ND
p, p'-DDT	ND	ND	ND	ND	ND	ND	ND
Mirex	ND	ND	ND	ND	ND	ND	ND
OTHER:							
WEIGHT (g)	75.0	63.7	90.8	92.1	92.1	81.6	64.1
MOISTURE (%)	73.0	69.5	70.5	73.0	73.0	66.5	70.5
LIPID (%)	1.95	5.25	4.60	2.40	2.30	8.70	2.80

Lower Level of Detection = 0.01 ppm for Tissue, Soil, Etc. 0.05 for Toxaphene and PCBs.
For Water, LLD= 0.005 ppm for OCs, Tox , PCBs
**Spike = ppm for
* = Confirmed by GC/Mass Spectrometry
*ND = None Detected
***NS = Not Spiked

Larry Lane
Signature

Appendix D
Comparison of Lower Fox River and API/PC/KR Exposure Concentrations

Comparison of Lower Fox River and API / PC / KR Exposure Concentrations and Results of Risk /Hazard Scaling

Changes from Outside Review

RME : Reasonable Maximum Exposure (represents high - end exposure)

CTE : Central tendency Exposure (represents more typical exposure)

For calculation of EPC : two calculations were performed

1) Upper bound measured concentration - the lower of the 95% UCL on the arithmetic mean or the max. detected conc. (whichever is lower)

2) Average measured concentration - arithmetic mean

3) For CDM estimated risk calculations are based on : CDM maximum = FR RME Upperbound concentration and risk ; CDM average = FR CTE average conc. and risk

Pathway	Fox River Statistical Analysis	Risk [3]	Fox River PCB Conc. [1]	Units	Exceeded Cancer Risk / HI	Area	Kalamazoo Stat. Analysis	Kalamazoo PCB Conc [1]	Units	Estimated Kalamazoo Risk	Exceeded Cancer Risk / HI
rec. angler											
ingestion of fish	Cancer RME - Upperbound Conc.	4.4E-03	5.783	mg/kg	Y	Green Bay	maximum	17.31	mg/kg	1.31E-02	Y
	Cancer RME - Average Conc.	3.8E-03	3.664	mg/kg	Y	Green Bay	average	7.6	mg/kg	8.93E-04	Y
	Cancer CTE - Average Conc.	4.3E-04	3.664	mg/kg	Y	Green Bay					
	NonCancer RME - Upperbound Conc.	1.2E+02	5.783	mg/kg	Y	Green Bay	maximum	17.31	mg/kg	3.74E+02	Y
	NonCancer RME - Average Conc.	8.4E+01	3.975	mg/kg	Y	Appleton to Lil. Rapids	average	7.6	mg/kg	4.09E+01	Y
	NonCancer CTE - Average Conc.	2.1E+01	3.975	mg/kg	Y	Appleton to Lil. Rapids					
ingestion/dermal contact w/surface water	Cancer RME - Upperbound Conc.	1.2E-07	2.11E-05	mg/L		DePere to GB	maximum	7.10E-05		3.51E-07	
	Cancer RME - Average Conc.	1.0E-07	2.16E-05	mg/L		DePere to GB	median	2.50E-05		1.16E-07	
	Cancer CTE - Average Conc.	1.7E-08	2.16E-05	mg/L		DePere to GB					
	NonCancer RME - Upperbound Conc.	6.0E-03	1.44E-05	mg/L		Lil. Lake Buttes des Morts	maximum	7.10E-05		2.93E-03	
	NonCancer RME - Average Conc.	3.0E-03	1.11E-05	mg/L		Lil. Rapids to De Pere	median	2.50E-05		2.23E-03	
	NonCancer CTE - Average Conc.	1.0E-03	1.11E-05	mg/L		Lil. Rapids to De Pere					
No Sediment since anglers assumed to be wearing boots - covered in wader scenario											
subsistence angler											
ingestion of fish	Cancer RME - Upperbound Conc.	6.0E-03	5.783	mg/kg	Y	Green Bay	maximum	17.31	mg/kg	1.80E-02	Y
	Cancer RME - Average Conc.	3.8E-03	3.664	mg/kg	Y	Green Bay	average	7.6	mg/kg	1.21E-03	Y
	Cancer CTE - Average Conc.	4.0E-04	3.664	mg/kg	Y	Green Bay					
	NonCancer RME - Upperbound Conc.	2.7E+02	5.783	mg/kg	Y	Green Bay	maximum	17.31	mg/kg	5.13E+02	Y
	NonCancer RME - Average Conc.	1.2E+02	3.975	mg/kg	Y	Appleton to Lil. Rapids	average	7.6	mg/kg	5.77E+01	Y
	NonCancer CTE - Average Conc.	3.0E+01	3.975	mg/kg	Y	Appleton to Lil. Rapids					
ingestion/dermal contact w/surface water	Cancer RME - Upperbound Conc.	1.6E-07	2.11E-05			DePere to Green Bay	maximum	7.10E-05	mg/L	4.72E-07	
	Cancer RME - Average Conc.	1.6E-07	2.16E-05			DePere to Green Bay	median	2.50E-05	mg/L	2.78E-08	
	Cancer CTE - Average Conc.	2.4E-08	2.16E-05			DePere to Green Bay					
	NonCancer RME - Upperbound Conc.	8.0E-03	1.44E-05			Little Lake Butte des Mort	maximum	7.10E-05	mg/L	3.94E-02	
	NonCancer RME - Average Conc.	6.0E-03	9.20E-06			Little Rapids to DePere	median	2.50E-05	mg/L	3.44E-03	
	NonCancer CTE - Average Conc.	2.0E-03	9.20E-06			Little Rapids to DePere					
No Sediment since anglers assumed to be wearing boots - covered in wader scenario											
Hunter											
ingestion of waterfowl	Cancer RME - Upperbound Conc.	1.1E-04	1.7	mg/kg	Y	Little Rapids to DePere	maximum	300	mg/kg	4.53E-02	Y
	Cancer RME - Average Conc.	4.3E-05	0.424	mg/kg	Y	Green Bay	average	39.3	mg/kg	3.96E-03	Y
	Cancer CTE - Average Conc.	3.4E-05	0.424	mg/kg	Y	Green Bay					
	NonCancer RME - Upperbound Conc.	4.3E+00	1.7	mg/kg	Y	Little Rapids to DePere	maximum	300	mg/kg	1.17E+03	Y
	NonCancer RME - Average Conc.	1.4E+00	0.541	mg/kg	Y	Appleton to Little Rapids	average	39.3	mg/kg	7.54E+01	Y
	NonCancer CTE - Average Conc.	4.9E-01	0.541	mg/kg		Appleton to Little Rapids					
ingestion/dermal contact w/surface water	Cancer RME - Upperbound Conc.	1.50E-08	2.41E-05			DePere to Green Bay	maximum	7.10E-05	mg/L	4.43E-08	
	Cancer RME - Average Conc.	1.50E-08	2.16E-05			DePere to Green Bay	median	2.50E-05	mg/L	1.97E-09	
	Cancer CTE - Average Conc.	4.30E-09	2.16E-05			DePere to Green Bay					
	NonCancer RME - Upperbound Conc.	1.00E-03	1.44E-05			Little Lake Butte des Morts	maximum	7.10E-05	mg/L	4.92E-03	
	NonCancer RME - Average Conc.	1.00E-03	1.11E-05			Little Rapids to DePere	median	2.50E-05	mg/L		

Pathway	Fox River Statistical Analysis	Risk [5]	Fox River PCB Conc. [4]	Units	Exceeded Cancer Risk / HI	Area	Kalamazoo Stat. Analysis	Kalamazoo PCB Conc. [3]	Units	Estimated Kalamazoo Risk	Exceeded Cancer Risk / HI
	NonCancer CTE - Average Conc.	0	—			—					
Local Resident inhalation of indoor/outdoor air	Cancer RME - Upperbound Conc.	1.80E-07	2.40E-05	mg/L		DePere to Green Bay	maximum	1.20E-04	mg/L	9.00E-07	
	Cancer RME - Average Conc.	not looked at	—			—	average	7.50E-05	mg/L		
	Cancer CTE - Average Conc.	not looked at	—			—	95% UCL	1.00E-04	mg/L		
	NonCancer RME - Upperbound Conc.	3.06E+00	1.44E-05	mg/L	Y	Little Lake Butte des Mortes	maximum	1.20E-04	mg/L	3.16E+01	Y
	NonCancer RME - Average Conc.	not looked at	—			—	average	7.50E-05	mg/L		
	NonCancer CTE - Average Conc.	not looked at	—			—	95% UCL	1.00E-04	mg/L		
recreational swimmer ingestion/dermal contact w/surface water	Cancer RME - Upperbound Conc.	6.80E-08	2.41E-05	mg/L		DePere to Green Bay	maximum	7.10E-05	mg/L	2.00E-07	
	Cancer RME - Average Conc.	not looked at	—				median	2.50E-05	mg/L		
	Cancer CTE - Average Conc.	not looked at	—								
	NonCancer RME - Upperbound Conc.	1.40E-02	2.41E-05	mg/L		DePere to Green Bay	maximum	7.10E-05	mg/L	4.13E-02	
	NonCancer RME - Average Conc.	not looked at	—				median	2.50E-05	mg/L		
	NonCancer CTE - Average Conc.	not looked at	—								
ingestion/dermal contact w/sediment	Cancer RME - Upperbound Conc.	8.70E-08	5.527	mg/kg		Little Lake Butte des Mortes	maximum	156	mg/kg		
	Cancer RME - Average Conc.	not looked at	—				average	3.7	mg/kg	5.82E-08	
	Cancer CTE - Average Conc.	not looked at	—				95% UCL	13.6	mg/kg	2.14E-07	
	NonCancer RME - Upperbound Conc.	3.5E-02	5.527	mg/kg		Little Lake Butte des Mortes	maximum	156	mg/kg		
	NonCancer RME - Average Conc.	not looked at	—				average	3.7	mg/kg	1.67E-02	
	NonCancer CTE - Average Conc.	not looked at	—				95% UCL	13.6	mg/kg	6.15E-02	
recreational wader ingestion/dermal contact w/surface water	Cancer RME - Upperbound Conc.	7.80E-09	2.41E-05	mg/L		DePere to Green Bay	maximum	7.10E-05	mg/L	2.30E-08	
	Cancer RME - Average Conc.	not looked at	—				median	2.50E-05	mg/L		
	Cancer CTE - Average Conc.	not looked at	—								
	NonCancer RME - Upperbound Conc.	2.0E-03	1.44E-05	mg/L		Little Lake Butte des Mortes	maximum	7.10E-05	mg/L	9.81E-03	
	NonCancer RME - Average Conc.	not looked at	—				median	2.50E-05	mg/L		
	NonCancer CTE - Average Conc.	not looked at	—								
ingestion/dermal contact w/sediment	Cancer RME - Upperbound Conc.	1.90E-07	5.527	mg/kg		Little Lake Butte des Mortes	maximum	156	mg/kg		
	Cancer RME - Average Conc.	not looked at	—				average	3.7	mg/kg	1.27E-07	
	Cancer CTE - Average Conc.	not looked at	—				95% UCL	13.6	mg/kg	4.68E-07	
	NonCancer RME - Upperbound Conc.	2.30E-02	5.527	mg/kg		Little Lake Butte des Mortes	maximum	156	mg/kg		
	NonCancer RME - Average Conc.	not looked at	—				average	3.7	mg/kg	1.67E-02	
	NonCancer CTE - Average Conc.	not looked at	—				95% UCL	13.6	mg/kg	6.15E-02	

Appendix E
Toxicity Profile for Polychlorinated Biphenyls

Appendix E
Toxicity Profile for Polychlorinated Biphenyls

Polychlorinated biphenyls (PCBs) are a group of synthetic organic chemicals consisting of 209 individual compounds, or congeners. A congener may have between 1 and 10 chlorine atoms located at various positions on the PCB molecule. Monochlorobiphenyls have one chlorine atom per molecule; dichlorobiphenyls have two chlorine atoms per molecule. This pattern progresses up through decachlorobiphenyls with ten chlorine atoms per molecule.

There are no known natural sources of PCBs. Before 1977, PCBs entered the water, air and soil during their manufacture and use. PCBs also entered the environment as a result of spills, leaks or fires in capacitors or transformers containing PCBs. PCBs can enter the environment today through poorly maintained hazardous waste sites, illegal or improper dumping of wastes, or disposal of PCB-containing consumer products into municipal landfills not designed to handle hazardous waste. Municipal and industrial incinerators that burn organic wastes can also release PCBs into the environment (ATSDR 1998).

PCBs were used extensively in the United States from the 1930s through 1977, when the manufacture of PCBs was banned. PCBs mixtures have several chemical and physical properties, which made them useful in a variety of industrial applications including resistance to acids and bases as well as oxidation and reduction; compatibility with organic materials; and thermal stability and nonflammability. The major uses of PCBs were as dielectric fluids in capacitors and transformers; as additives in paint, plastics, newspaper print, and dyes; as extenders in pesticides; and as heat transfer and hydraulic fluids (Kimbrough, et al. 1999).

People may be exposed to PCBs from the workplace and from the environment. Exposures occur through contact with air, water, soil, breast milk, and food. Exposure can also occur in utero. The primary pathway of exposure to PCBs in the Great Lakes region is through the food pathway, particularly through the consumption of fish (ATSDR 1998). Susceptible populations include certain ethnic groups, sport anglers, the elderly, pregnant women, children, fetuses and nursing infants.

Summary of Health Effects Associated with PCBs - Human Health Studies

The Agency for Toxic Substances and Disease Registry (ATSDR) and the U.S. Environmental Protection Agency (EPA) have jointly developed a technical paper, Public Health Implications of Polychlorinated Biphenyls (PCBs) Exposure. Human health studies discussed in this paper indicate that exposure to PCBs have been linked to the following health effects:

- Reproductive function in women
- Neurobehavioral and development deficits in newborns and school-age children from in utero exposure
- Liver disease, immune function impacts, and thyroid effects
- Increased cancer risks

Several studies have demonstrated a correlation between fish consumption by mothers and developmental disorders and cognitive deficits in children. In the first of these studies, conducted by Jacobson (Jacobson, et al. 1985, 1990a, 1990b, 1996), statistically significant decreases in gestational age, birth weight, and head circumference were observed and continued to be evident 5 to 7 months after birth. Neurobehavioral deficits were observed including depressed responsiveness, impaired visual recognition, and poor short-term memory at 7 months of age, which continued to be present at 4 years of age. While recognized limitations exist in these studies, including the pooling of blood samples, which is no longer a recognized technique, more recent studies have provided confirmatory evidence of the relationship between PCB exposure and developmental effects.

In a study of prenatal exposure and neonatal behavioral assessment scale (NBAS) performance, cord blood PCBs, DDE, HCB, Mirex, lead, and hair mercury levels were determined for 152 women who reported never consuming Lake Ontario fish and 141 women who reported consuming at least 40 PCB-equivalent pounds of Lake Ontario Fish over a lifetime. PCBs were related to impaired performance on those NBAS clusters associated with fish consumption, namely, Habituation and Autonomic clusters. Results revealed significant linear relationships between the most heavily chlorinated PCBs and performance impairments 25 to 48 hours after birth. Higher prenatal PCB exposure was also associated with nonspecific performance impairment (Stewart, et al. 2000). PCBs of lighter chlorination were unrelated to NBAS performance.

Studies in Japan and Taiwan of PCB exposure from consumption of contaminated rice oil have contributed to the evidence of an association between PCBs and neurobehavioral effects. The illnesses were originally referred to as Yusho disease in Japan and Yu-Cheng disease in Taiwan. In earlier studies (Bandiera, et al. 1984; Kunita, et al.; Masuda and Yoshimura 1984; Ryan, et al. 1990; ATSDR 1993) co-contaminants in the rice oil, particularly chlorinated dibenzofurans (CDFs), were considered to be the primary causal agent. Recent studies, however, involving a re-examination of previous studies and newer results from a study of children born later to exposed mothers have demonstrated developmental delays associated with maternal exposure to PCBs and CDFs (Guo, et al. 1995; Chao, et al. 1997).

A study of Inuit women from Hudson Bay indicated an association between levels of PCBs and dichlorodiphenylethene (DDE) in breast milk and a statistically significant reduction in male birth length (Dewailley, et al. 1993a). No significant differences were observed between male and female newborns for birth weight, head circumference, or thyroid-stimulating hormone.

A study of 338 infants of mothers occupationally exposed to PCBs during the manufacture of capacitors indicated a decrease in gestational age (6.6 days) and a reduction in birth weight (153 grams) at birth in infants of mothers directly exposed to PCBs (Taylor, et al. 1984). A follow-up study of 405 women in this population demonstrated that serum total PCB levels in women with direct exposure to PCBs were more than four-fold higher than for women in indirect-exposure jobs. A decrease in birth weight and gestational age was found for the infants of these women (Taylor, et al. 1989).

Immune system effects on persons exposed to PCBs have been reported in several studies. A significant negative correlation between weekly consumption of fish containing PCBs from the Baltic Sea and white cell count was reported (Svensson 1994). Immune system effects were reported in Inuit infants who were believed to have received elevated levels of PCBs and dioxins from their mother's breast milk. Effects included a decline in the ratio of the CD4+ (helper) to CD8+ (cytotoxic) T-cells at ages 6 and 12 months (Dewailley, et al. 1993). Infants examined from birth to 18 months who were exposed to PCBs/dioxins in the Netherlands exhibited lower monocyte and granulocyte counts and increases in the total number of T-cells and the number of cytotoxic T-cells (Weisglas-Kuperous, et al. 1995). An increase in serum PCB levels was associated with a decrease in natural killer cells (Hagamar, et al. 1995).

Effects on the thyroid have been reported in a study of the Dutch population. Higher CDD, CDF, and PCB levels in human milk correlated significantly with lower plasma levels of maternal total triiodothyronine and total thyroxine and higher plasma levels of thyroid-stimulating hormone in infants during the second and third month after birth (ATSDR 1998).

Occupational studies show some increases in cancer mortality in workers exposed to PCBs. Significant excesses of cancer mortality were found for liver, gall bladder, and biliary tract cancer (Brown 1987), however, co-exposure to other chemicals in the workplace limits the strength of the association to PCBs. Mortality from gastrointestinal tract cancer in males and hematologic neoplasms in females was reported for capacitor workers in Italy (Bertazzi, et al. 1987). Limitations in this study include a small number of cases, short exposure period, and lack of pattern or trend when data were analyzed by duration of exposure. The results of these studies have been evaluated and are considered inconclusive by the ATSDR (1996).

Evidence of an association between exposure to PCBs by capacitor workers and mortality from malignant melanoma was reported (Sinks, et al. 1992). The workers were also exposed to various solvents. More deaths were observed than expected for malignant melanoma (8 observed versus 2 expected) and cancer of the brain and central nervous system (5 observed versus 2.8 expected). Limitations include a small number of cases, insufficient monitoring data, unknown contribution of exposure to solvents, and possible bias due to the healthy worker effect. The results of this study have been evaluated and are considered inconclusive by ATSDR.

A recent study of male and female capacitor workers reported mortality from all cancers was significantly below expected for hourly male workers and comparable to expected for female workers (Kimbrough, et al. 1999). Limitations with this study include:

- Exposed and unexposed workers were included as one group diluting any potential cancer findings
- 76 percent of the workers never had exposure to PCBs
- Only 4 percent of the workers had any PCB blood data and only 2 percent worked in jobs with high exposure to PCBs
- 79 percent of the workers who did die of cancer had PCB exposures less than 1 year

ATSDR has stated it is untenable to dismiss concerns for carcinogenicity of PCBs. In 1999, the ATSDR convened an Expert Panel Review of the Toxicological Profile for PCBs. The panel concurred that the Kimbrough study of General Electric capacitor workers could not be used to dismiss the carcinogenic potential of PCBs (Bove, et al. 1999).

For reasons such as those above, EPA also concludes that the limitations of the Kimbrough study prevent conclusions to be drawn regarding the carcinogenicity of PCBs. While all human studies have limitations and confounders, controlled animal studies, such as a long term bioassay conducted by General Electric (Mayes 1998) provide conclusive evidence that PCBs, including the lower chlorinated forms (i.e., Aroclor 1016 and 1242) cause cancer. For this reason, the International Agency for Research on Cancer (IARC) and EPA have concluded that the PCBs are probable human carcinogens. These conclusions are independently consistent with the National Toxicology Program's eight Report on Carcinogens, which lists PCBs as "reasonably anticipated to be human carcinogens."

A recent study demonstrated a strong dose-response relationship between total lipid-corrected serum PCB concentrations and the risk of non-Hodgkin lymphoma (Rothman, et al. 1997). These findings are consistent with another study where residues of PCBs in adipose tissue of non-Hodgkin's lymphoma patients were higher than those of control patients (Hardell, et al. 1996). In studies of capacitor workers, significantly increased risks were reported for lymphatic/haematological malignant (LHM) diseases among female capacitor workers but non-significant increases were found for male workers (Bertazzi, et al. 1987). Two other studies found no evidence of increase in LHM among workers (Brown 1987; Sinks, et al. 1992).

Animal Studies

Four PCB mixtures - Aroclor 1016, 1242, 1254, and 1260 have induced liver tumors when fed to female rats. Aroclor 1260 also induced liver tumors in male rats (Mayes, et al. 1998). Thyroid gland tumors were induced in male rats in the same studies. Lifetime dietary exposure to PCB mixtures with 60 percent chlorine induced liver tumors in three rat strains (Kimbrough, et al. 1975; Schaeffer, et al. 1984; Norback and Weltman 1985; Moore, et al. 1994). The Mayes study provided strong evidence that all PCB mixtures can cause cancer. Based on animal studies, IARC has concluded that PCBs are probable human carcinogens.

Other health effects observed in animals exposed to PCB include neurotoxicity, thyroid gland effects, immune system effects, and reproductive effects. Neurobehavioral effects in the offspring of monkeys have been associated with Aroclors 1248, 1242, and 1016 (Bowman, et al. 1978; Levin, et al. 1988; Schantz, et al. 1989; and Rice 1999). Rats exposed to PCBs exhibited thyroid gland enlargement, reduced follicular size, follicular cell hyperplasia, abnormally shaped lysosomes in the follicular cells, and decreased levels of adrenal cortex hormones which were dose-related (Byrne, et al. 1987, 1988).

Rats treated with Aroclor 1254 had reduced thymus weights and reduced natural killer cell activities (Smialowicz, et al. 1989). Monkeys exposed to Aroclor 1254 had a significant decrease in IgM and IgG levels in primary response to challenge with sheep red cells (Tryphonas, et al. 1989). Effects on the immune system, demonstrated in several species, form the basis of the EPA reference dose (RfD) for Aroclor 1254 (ATSDR 1998).

Monkeys exposed in utero and through breast milk to PCBs exhibited lower birth weights, hyperpigmentation, and significantly impaired neurobehavioral test results (Schantz 1989, 1991).

Health Studies in the Great Lakes Basin

Research indicates that the primary pathway of exposure to PCBs in the Great Lakes region is from fish consumption. Recent evidence indicates an association between PCB exposures through fish consumption and reproductive and developmental effects. Newborns of mothers in the high fish consumption category exhibited a greater number of abnormal reflexes, less mature autonomic responses and less attention to visual and auditory stimuli (Lonky, et al. 1996).

The Lake Michigan Maternal Infant Cohort study was the first epidemiologic investigation to demonstrate an association between the self-reported amounts of Lake Michigan fish eaten by pregnant women and behavioral deficits in their newborns. The 242 infants born to mothers who had eaten the greatest amount of contaminated fish during pregnancy had (1) more abnormally weak reflexes; (2) greater motor immaturity and more startle responses; and (3) less responsiveness to stimulation (ATSDR 1998). A follow-up examination of 212 children indicated that the neurodevelopmental deficits found during infancy and early childhood still persisted at age 11 years (Jacobsen and Jacobsen 1996).

In a study of nervous system dysfunction in adults exposed to PCBs and other persistent toxic substances, motor slowing and attention difficulties were directly related to the frequency of consumption of St. Lawrence Lakes fish (Mergler 1997, 1998).

In an ongoing study of Native Americans in Minnesota, Wisconsin, and Michigan preliminary results indicated elevated serum PCB levels were correlated with self-reported diabetes and liver disease (Dellinger, et al. 1997; Tarvis, et al. 1997; Gerstenberger, et al. 1997). The average annual fish consumption rate was 23 grams per day.

In a study of the PCB congener profile in the serum of humans consuming Great Lakes fish, an established cohort of persons with robust exposure to contaminants in recreationally caught Great Lakes fish were shown to have significant quantities of serum PCBs still present 15 years after enrollment in the study. The current levels of PCBs in this group were far above those found in enrollees of more recent fish eater studies. Identification of the PCB profile in fish eaters and non-fish eaters revealed the presence of several congeners that have the potential to affect biologic or health outcomes. Investigators are currently in the process of evaluating neuropsychologic function and thyroid function in the Lake Michigan fish eaters for which PCB congener profiles were established (Humphrey, et al. 2000).

The Kalamazoo River Angler Survey (MDCH 2000b) included a second phase that included a health survey and biological testing. In this second phase, individual self-reported medical information and fish consumption patterns was obtained and chemical analyses for PCBs, DDE, and mercury was performed on blood samples of 151 out of the original 938 survey participants. The study attempted to analyze for possible associations between chemical residue levels and self-reported health problems for fish eaters and compared chemical residue data from this study cohort to other fish eating populations previously studied.

The study reported that "medical problems reported as subjective symptoms (upset stomach, nausea, headache, or dizziness) were not measurable or quantifiable in an objective way. Statistically significant associations were not found between contaminant residues levels and self-reported medical problems. However, those anglers who considered themselves to be in good health appeared to be less likely to have blood PCB levels exceed median values for the aggregate group than anglers who considered themselves to be in fair/poor health."

Significantly higher levels of PCBs were found in fish eaters compared with non-fish eaters. The geometric mean for fish eaters was 2.1 ppb PCBs in blood and for non-fish eaters was 1.11 ppb PCBs in blood. Increasing residue levels for PCBs suggested a good correlation with age reflecting the persistence of these compounds in human tissues and possible higher past exposures. In contrast to previous studies of sport anglers, the Kalamazoo River Survey appears to indicate lower exposure to PCBs. Lake Michigan open water fish eaters were first evaluated in 1979-1980 and reevaluated in 1989 (Humphrey 1988; Hovinga, et al. 1992). The Lake Michigan fish eaters consumed an annual average of 32 pounds (64 meals per year) of sport-caught fish, whereas the Kalamazoo anglers consumed an annual average of 9 pounds (18 meals per year) of sport-caught fish. The Kalamazoo fish eaters more closely resembled the non-fish eaters in the Lake Michigan study.

In a comparison of Kalamazoo anglers with a survey of anglers on Wisconsin inland lakes and rivers (Fiore 1989), the following was observed: (1) Kalamazoo anglers ate on average less fish than the Wisconsin anglers but had higher PCB levels; (2) 59 of the Wisconsin anglers had no detectable PCBs while only 10 Kalamazoo River anglers were nondetectable; (3) the upper range of serum PCBs (73 ppb) reported in Kalamazoo was more than two and one-half times the upper range seen in Wisconsin (27.1 ppb).

Limitations of Phase II of the Kalamazoo River Angler Survey include: (1) selection bias in that the study group was self-selected; (2) fish consumption within the past 12 months was used as the exposure variable, rather than historic consumption; (3) response bias due to participants knowing the purpose of the study; and (4) biases associated with self-reporting health effects.

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